AN EVALUATION OF THE HARBORS OF SUBIC BAY AND MANILA, REPUBLIC OF THE PHILIPPINES, AS TYPHOON HAVENS

John Allen Douglass

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THESIS

An Evaluation of the Harbors of Subic Bay and Manila, Republic of the Philippines, as Typhoon Havens

by

John Allen Douglass

September 1974

Thesis Advisor: G. J. Haltiner

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This study evaluates the harbors of Subic Bay and Manila as possible typhoon havens. Characteristics of the harbors under tropical cyclone conditions, including climatology, topographical effects on the wind, and reliability of moorings and anchorages at each harbor are discussed. Problem areas to be considered if remaining in port and suggested evasion procedures for ships sailing from the port are examined. The

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tracks of tropical cyclones from 1884-1973 for the western North Pacific were analyzed to assess the threat posed to each harbor by a tropical cyclone. Results suggest that neither port is an entirely safe haven. Subic Bay could be a haven under certain specified conditions while Manila should never be considered a typhoon haven. To aid commanding officers, operationally oriented flow diagrams are presented which summarize the locations of the various sections of the text that could be used in decision making.

An Evaluation of the Harbors of Subic Bay
and Manila, Republic of the Philippines,
as Typhoon Havens

by

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Submitted in partial fulfillment of the
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1. INTRODUCTION

1.1 BACKGROUND

The tropical cyclone, and in particular the typhoon, presents one of the most awesome and difficult problems to all Fleet units in the western North Pacific Ocean (WESTPAC). In recent years, the accuracy of forecasting typhoon direction and speed of movement has vastly increased. However, this increase in accuracy has not reached the level of eliminating a basic decision by commanders of Fleet units; namely, when faced with a typhoon threat whether to seek or remain in the shelter of a harbor or to take evasive action and ride out the storm at sea.

For most WESTPAC harbors there are insufficient or inadequate data available to the Fleet unit commander upon which to base a truly knowledgeable decision. Previous studies on the harbors of Hong Kong (Mautner and Brand, 1973) and Kaohsiung and Chilung (Keelung) in Taiwan (Brown, 1974) have been completed and should provide much information about these harbors. This study examines the harbors of Subic Bay and Manila in the Philippine Islands as possible "Typhoon Havens."

The multitude of variables involved make it practically impossible to classify a certain harbor as "safe" or "unsafe." This study will examine meteorological, oceanographic, topographical, and individual port characteristics in an effort to evaluate the harbors of Subic Bay and Manila as typhoon havens. However, there are other less tangible factors which must be considered, such as, for example, those included in the overall "measure of a harbor."

1.2 THE MEASURE OF A HARBOR

"The measure of a harbor is the sum total of many individual factors. It is in the extent of its shelter, depth of water at the piers, quantity and condition of its service craft and the efficiency of its port services. It is measured by the experience level of its port services officer. It is in the skill, spirit and will of his crews. It is in the emergency capability of the Ship Repair Facility to make a ship ready for sea. It is the quality of the typhoon warning service and the lead time provided the Senior Officer Present Afloat (SOPA) to make sound command decisions and to the Port Services Officer to carry out smoothly and efficiently his flexible plan of action. Finally, the measure of a harbor is knowledge of that harbor and all that it connotes in the mind of the Senior Officer Present Afloat who, by his decisions, will stamp it as a vital refuge to be taken or as an inanimate limited shelter to refuse as a harbor for the ships under his charge." (U.S. Fleet Weather Facility, Yokosuka, Japan, 1967.)

2. TROPICAL CYCLONES

2.1 DEFINITION AND CLASSIFICATION

A tropical cyclone is a low pressure disturbance whose central core is considerably warmer than the surroundings up to very high levels. It is differentiated from mid-latitude (extratropical), cold-core cyclones by its origin, dynamics, and the meteorological characteristics of the air masses involved. Like typical low pressure systems, the wind circulation in a tropical cyclone is counterclockwise about its center in the Northern Hemisphere and clockwise in the Southern Hemisphere.

By joint international agreement, tropical cyclones in the WESTPAC area are classified according to their intensity as follows:

Tropical Depression	- maximum sustained winds not exceeding 33 kt
Tropical Storm	- maximum sustained winds between 34 and 63 kt
Typhoon	- maximum sustained winds 64 kt or greater

2.2 DEVELOPMENT

The primary region of tropical cyclone development lies between latitude 25N and 25S, except very near the equator. The area between the latitudes 5N to 20N and from 170E longitude to the Philippine Islands produces more severe tropical storms than any region in the world. It is in this area that the water temperature is always above 26°C (78.8°F). Empirical data indicates that warm water such as this is a necessary condition for the development and intensification of tropical cyclones. These warm ocean waters over which the tropical cyclones travel provide the energy required for the growth and sustenance of the storm (Palmen and Newton, 1969).

2.3 MOVEMENT

Considering the WESTPAC region as a whole, the majority of typhoons conform to the usual tropical cyclone track pattern and move initially westward or west northwestward from the source region.[1] Those that reach higher latitudes, normally north of 20N, have a tendency to recurve and eventually move in a northeasterly direction over or to the east of Japan.[2] However, a considerable number of typhoons travel almost due westward, cross over the Philippines, and eventually dissipate over China or Southeast Asia. Prior to recurvature, most tropical cyclones move at speeds ranging from 8-12 kt. After recurvature, this speed of movement can accelerate within 48 hours to as much as 2-3 times the speed at the point of recurvature (Burroughs and Brand, 1972).

The course of individual storms cannot be said to follow any such standardized patterns. Numerous typhoons have followed extremely erratic courses, even making occasional loops in their tracks. For this reason the progress of each typhoon should be closely monitored for changes in intensity and direction and speed of movement.

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[1]See Appendix A for monthly climatological tracks of tropical cyclones in WESTPAC which at some time were of typhoon intensity.

[2]Recurvature - The westward progression of a tropical cyclone ceases and a northerly and finally northeasterly course results. Approximately 40% of WESTPAC tropical cyclones recurve.

2.4 WIND CIRCULATION AND INTENSITY

The wind systems of tropical cyclones vary greatly in size, from as little as 100 n mi in diameter to 1000 n mi or more. The shape of the wind system is more or less circular. At the periphery the winds are light, but they increase inward toward the center of the storm. Figure 1 depicts the wind pattern around a typical large, intense typhoon. Note that the winds in the right semicircle of the circulation are more intense. For this reason the right side of a tropical cyclone is known as the "dangerous semicircle."

There is a pronounced gustiness of the winds, even at the periphery; nearer the center the more violent winds occur in heavy squalls. In the center of a mature typhoon there is a region of calm or light winds, known as the "eye," which is surrounded by the strongest winds of the entire storm system.

2.5 SEA STATE

The appearance of sea swell is often the first and one of the most dependable precursors of the approach of a tropical cyclone. The rate of movement of these swells is usually 30 kt or more, so they rapidly outrun the storm field and are often observed many hundreds of miles in advance of the storm circulation.

Figure 2 shows the combined sea height[3] associated with 21 tropical storms and typhoons (based on 173 analyses for the year 1971) plotted as a function of distance from the tropical

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[3] The combined sea height is defined as the square root of the sum of the squares of "significant" sea and swell height. Sea represents wind waves and swell consists of wind generated waves which have advanced into regions of weaker or calm winds. "Significant" will be defined here as the average height of the highest one-third of the waves observed over a specified time.

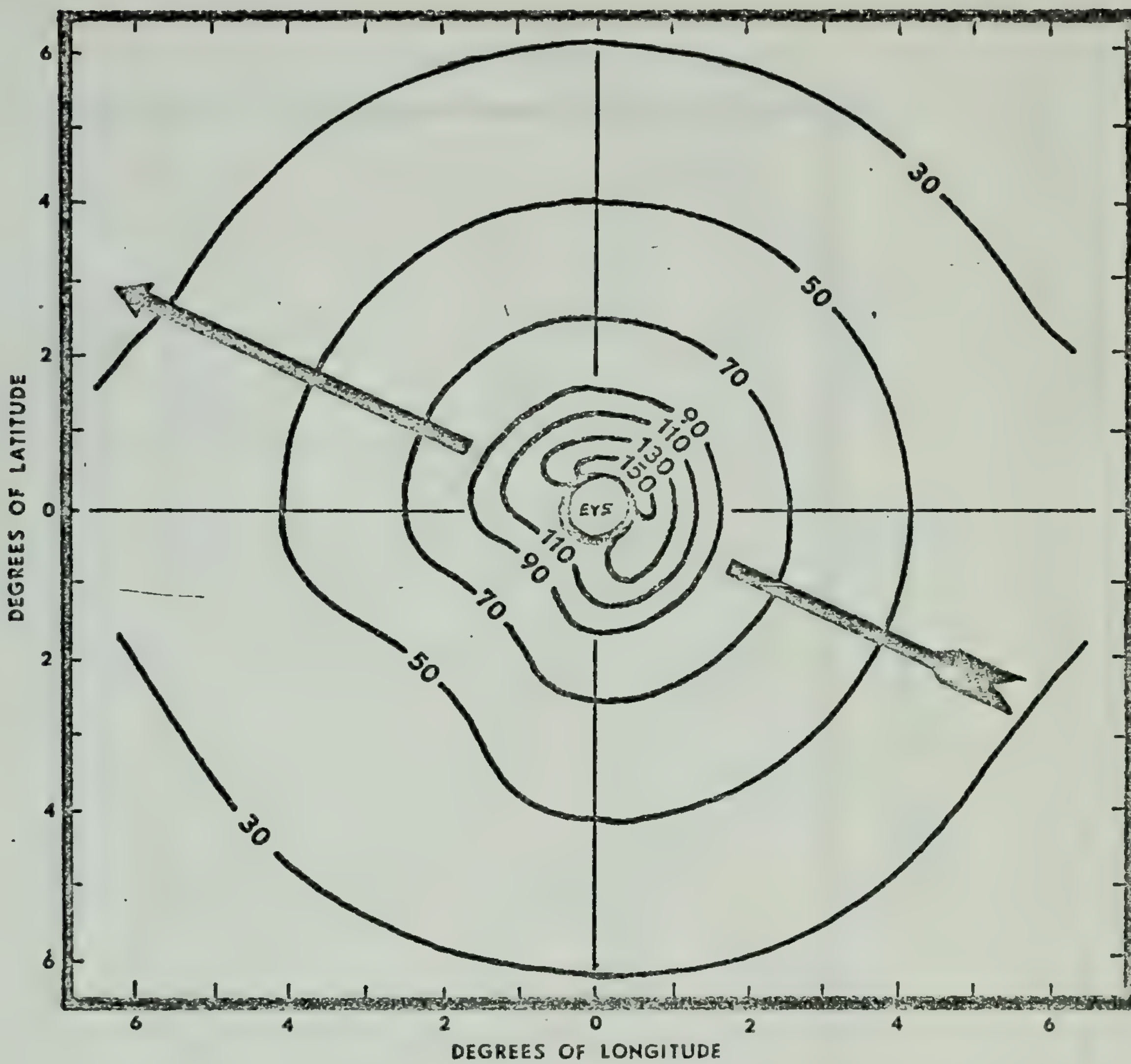

Figure 1. Distribution of surface wind speed (in knots) around a large, intense typhoon in the Northern Hemisphere over open water. The arrow indicates arbitrary direction of movement (after Harding and Kotsch, 1965).

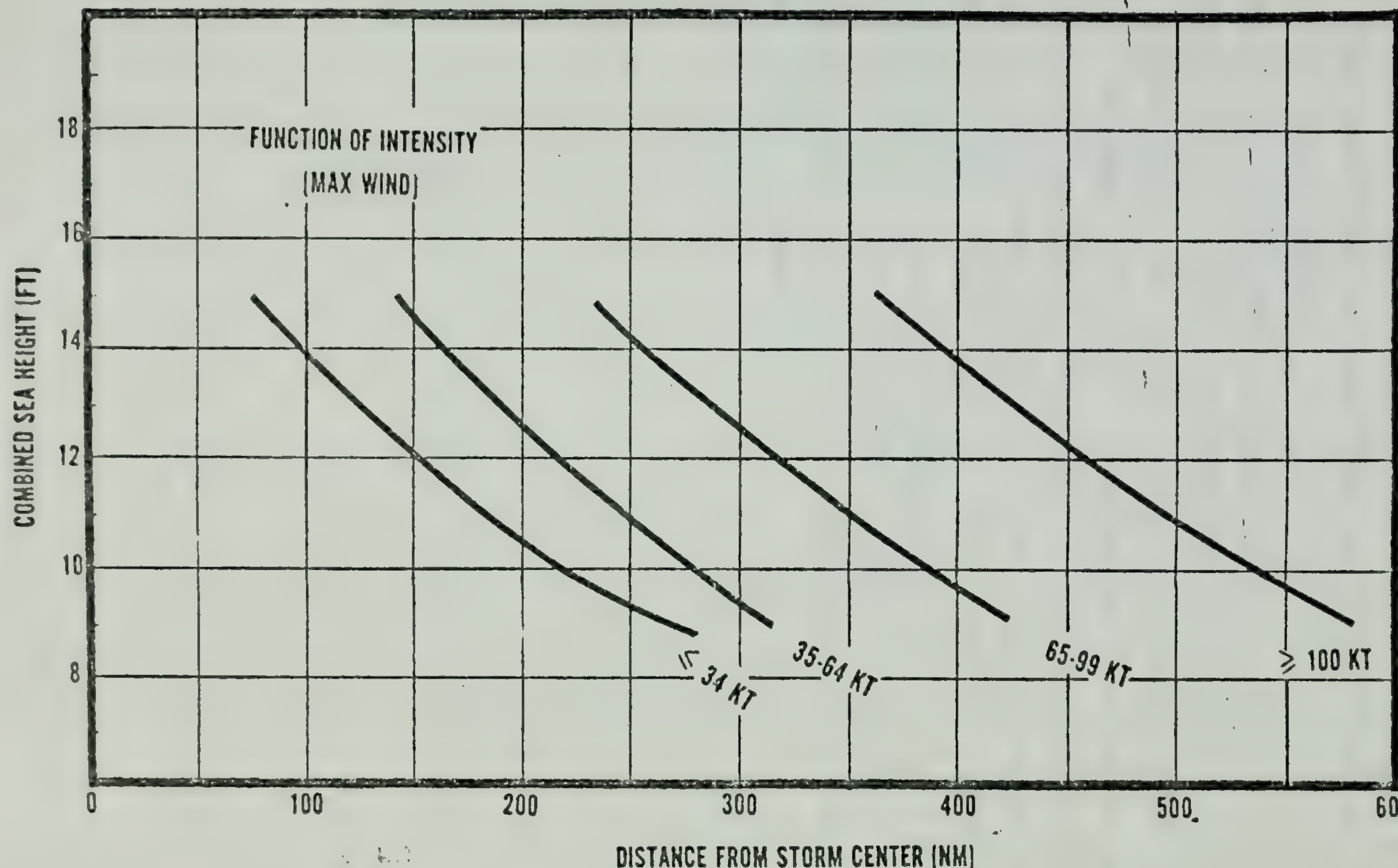

Figure 2. Combined sea height plotted against distance from tropical cyclone center and given as a function of storm intensity (Brand, <u>et al</u>., 1973).

cyclone center and tropical cyclone intensity. The large variation in the sea state with tropical cyclone intensity is quite evident. The distances indicated are mean distances since the isopleths of combined sea height are not symmetric about the storm center.

Figure 3 shows the average combined 9-15 ft sea height isopleths for tropical cyclones moving between 240° and 360°. It is based on 81 sea state analyses between 240°-300° and 66 analyses between 301°-360°. These analyses were for tropical cyclones that occurred during 1971. Notice that the greatest area of higher seas (9-15 ft range) exists to the rear and toward the right semicircle of the tropical cyclone. It should be noted that Figure 3 is applicable only to the WESTPAC area east of the Philippine Islands. Figures for the South China Sea are approximately 20% less than those for the above area (Brand, et al., 1973).

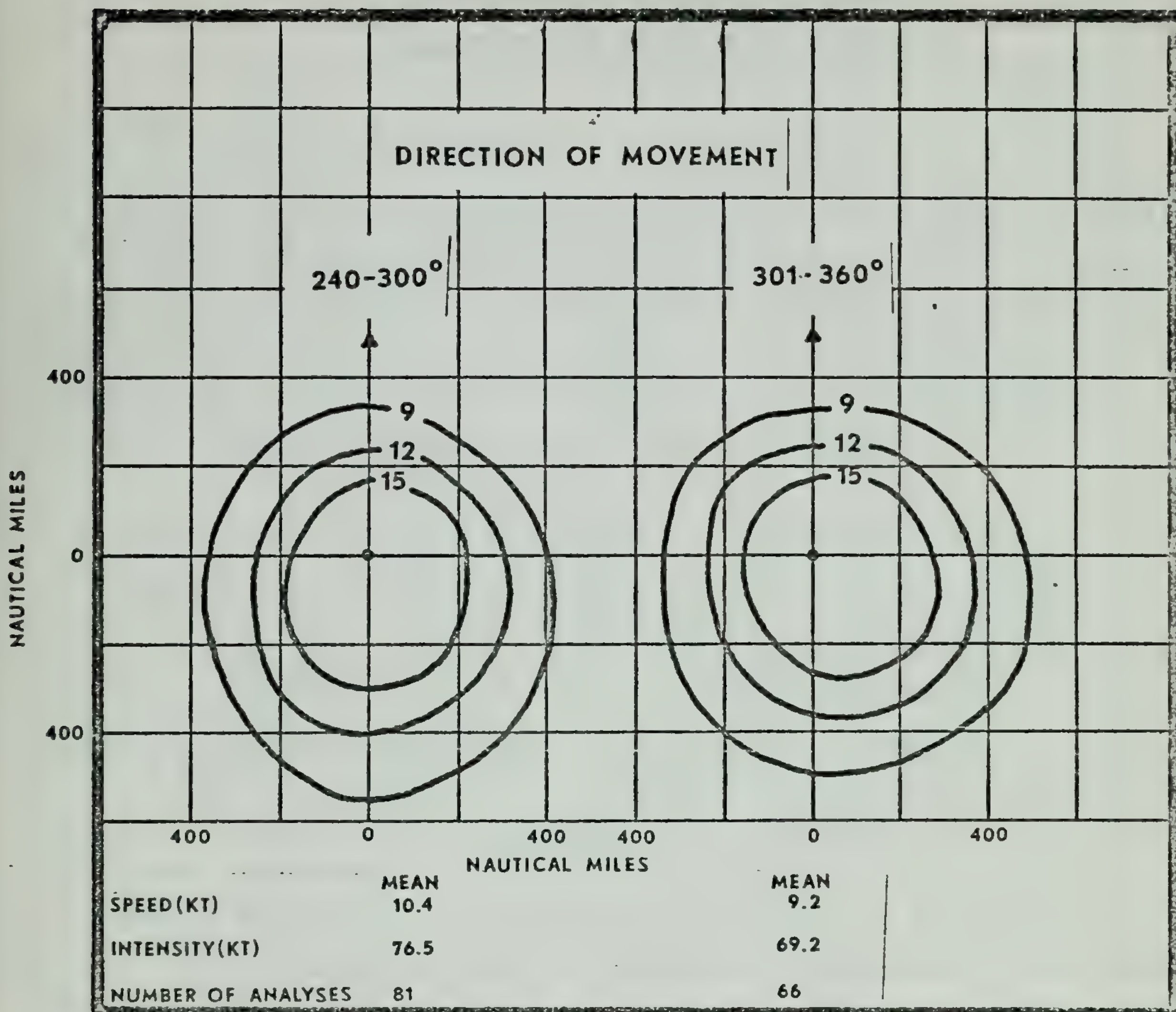

Figure 3. Combined sea-height isopleths (9-15 ft) for tropical cyclones heading between 240°-360° (after Brand, et al., 1973).

3. THE PHILIPPINE ISLANDS IN RELATION TO TROPICAL CYCLONES

3.1 GEOGRAPHICAL LOCATION

Figure 4 shows the geographical location of the Philippine Islands in the western North Pacific Ocean. The Philippines constitute the largest island group, in terms of numbers, of the Malay Archipelago. They consist of approximately 7100 islands and islets, of which Luzon is the largest, covering an area of approximately 115,600 square miles.

3.2 EFFECT OF PHILIPPINE ISLANDS ON TROPICAL CYCLONES

The degree of land influence on a tropical cyclone is a function of the area and topography over which the storm is passing. Figure 5 depicts the topography of the Philippine Islands. It can be seen that the terrain of the Philippine Islands varies a great deal, ranging from extensive mountainous regions on Luzon and Mindanao to a sea-land mix in the central Philippine Islands.

Brand and Blelloch (1972) showed that the intensity, speed, and circulation size of typhoons are greatly influenced by the Philippine Islands. Two of these parameter changes are depicted in Figures 6a and 6b. The typhoons used in this study were divided into two categories: intense typhoons, or those having an initial average intensity $\geq$90 kt in the 24-hr period prior to crossing the Philippines, and weak typhoons, or those having an average initial intensity $\leq$90 kt in the 24-hr period prior to crossing the Philippines. The intensity of intense typhoons decreased 45-50 percent in maximum sustained wind while the weak typhoons only decreased in intensity 10-15 percent. The speed of intense typhoons shows little decrease,

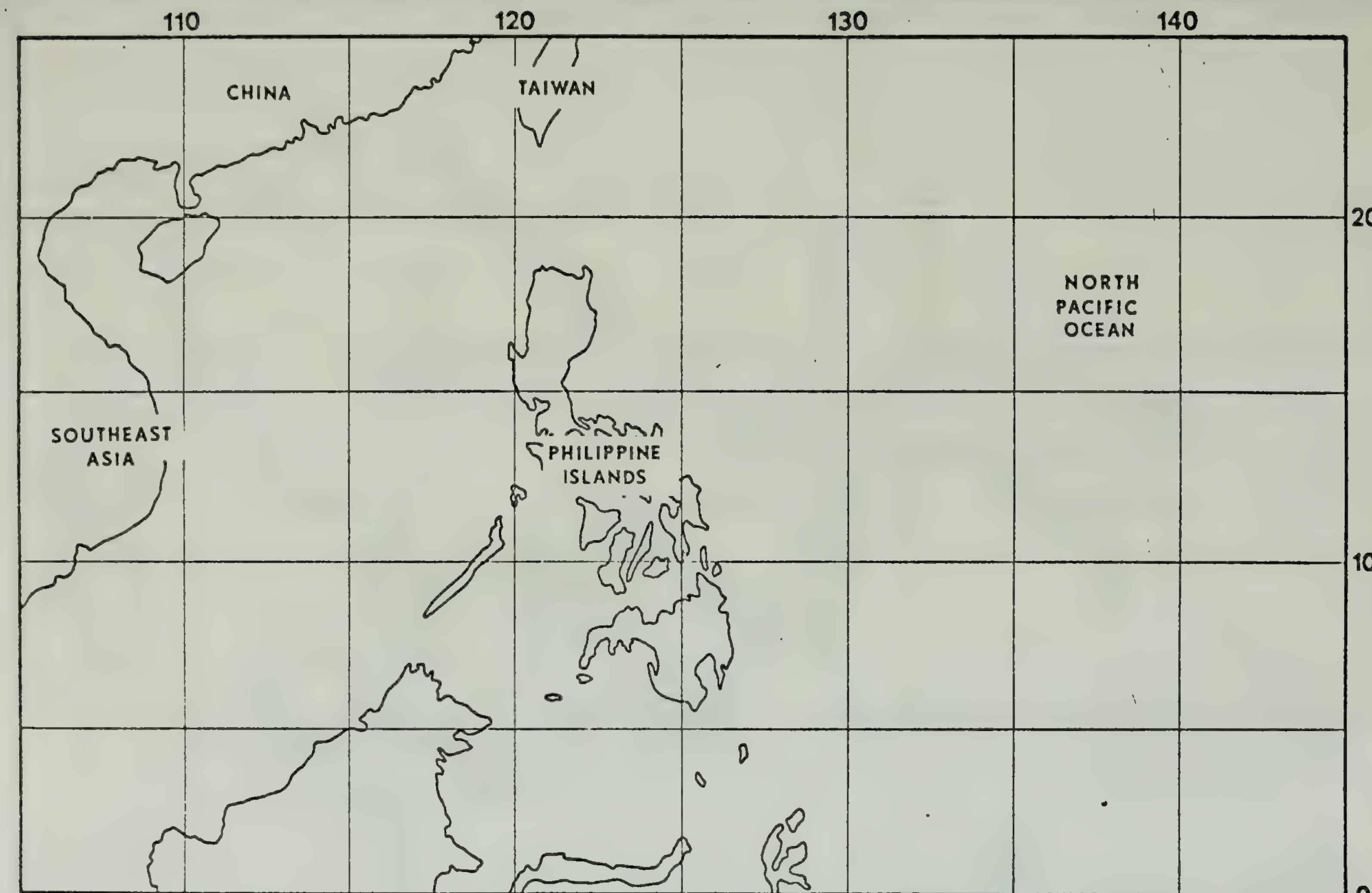

Figure 4. Map of the western North Pacific Ocean showing the positions of major land masses.

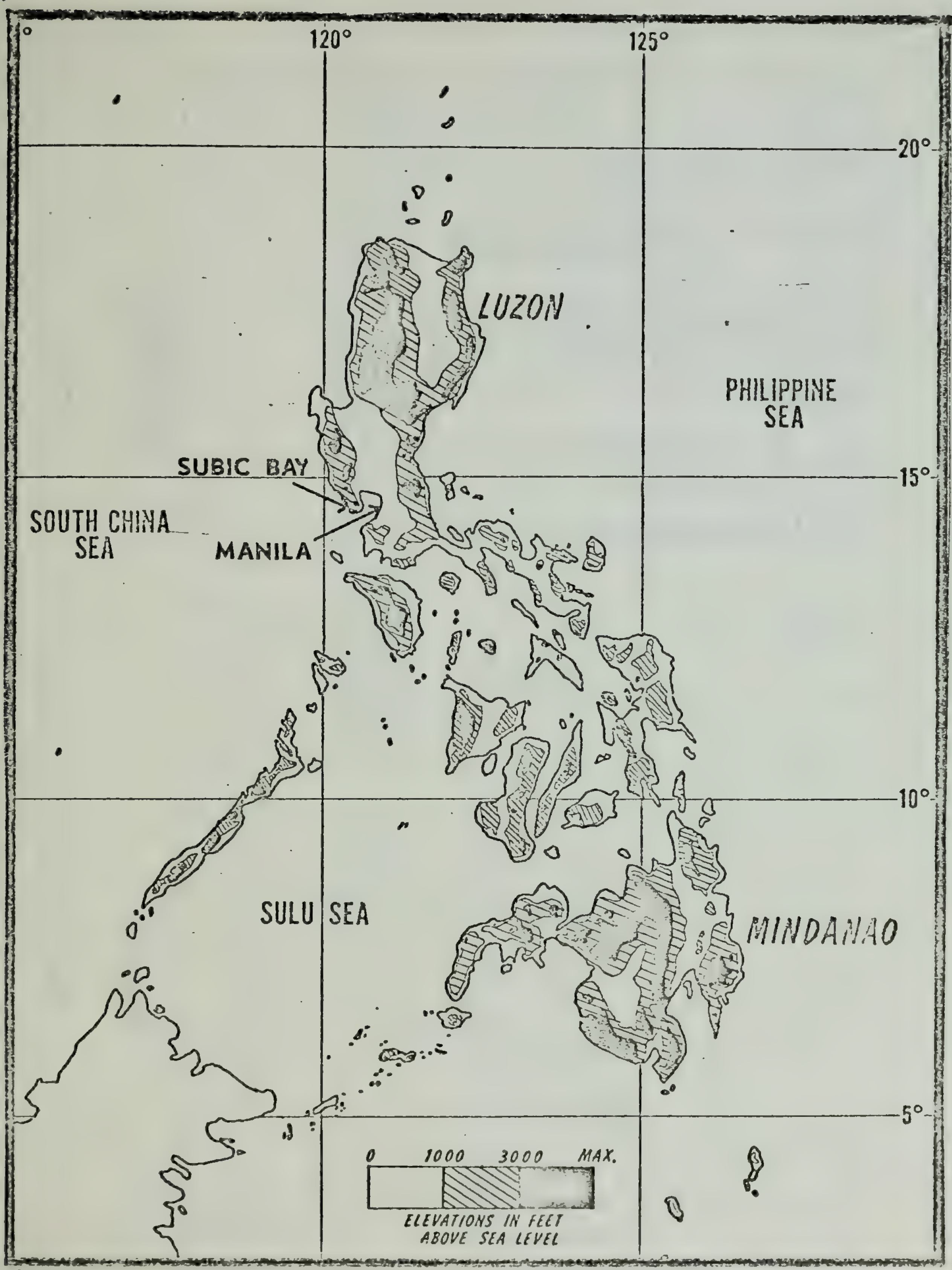

Figure 5. Topographical map of the Philippine Islands showing the location of Subic Bay and Manila.

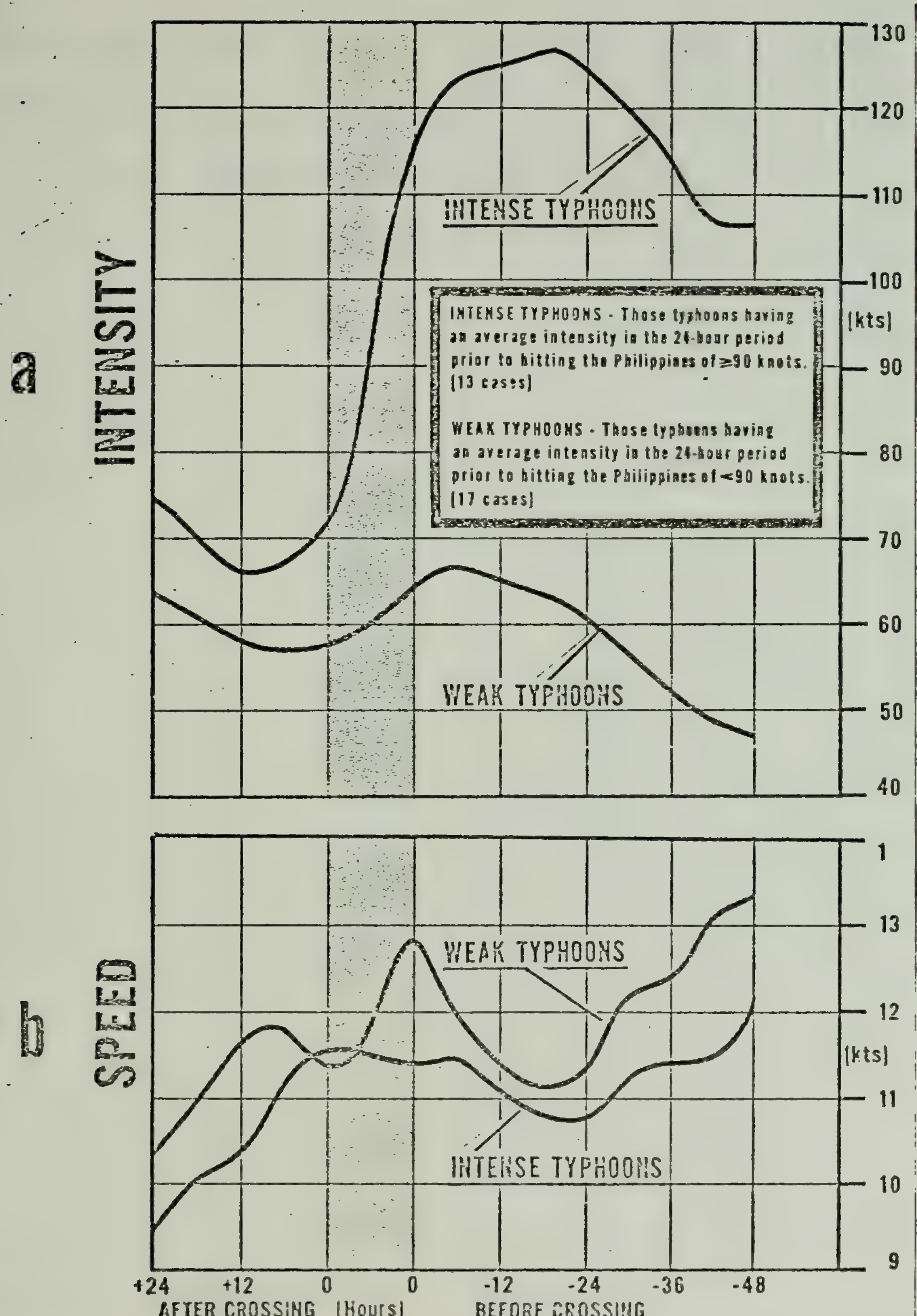

Figure 6. Average intensity (a) and speed (b) profiles for intense and weak typhoons crossing the Philippines (Brand and Blelloch, 1972).

while weaker typhoons, which move faster, show a marked decrease in speed (see Figure 6b). The circulation size of all typhoons considered decreased on an average of 17% in areal extent when crossing the Philippines.

4. SUBIC BAY

4.1 GEOGRAPHICAL LOCATION

Figures 5 and 7 depict the geographical location of Subic Bay on the island of Luzon. Subic Bay, centered near 14°50'N and 120°14'E, is approximately 4 n mi wide and 9 n mi long. The entrance to Subic Bay opens seaward to the southwest and Grande Island, located in the mouth of the bay, divides the entrance into two channels. The main channel, lying to the west of Grande Island is wide, deep, and clear of obstructions.

4.2 TOPOGRAPHY

Figure 7 depicts the topography of the terrain surrounding Subic Bay. The bay is surrounded by mountainous terrain in all directions except south-southwest. Peaks in excess of 4000 ft lie to the northeast with passes through the mountains to the east-northeast.

Figure 7 also depicts the bottom topography of Subic Bay. Depths in Subic Bay decrease regularly from 200 ft in the entrance to 50 ft at its head. The greater part of the bay, including the Port Olongapo complex, has been swept to a depth of 49 ft. The entrance channel across Subic Bay and into the Port Olongapo complex is approximately 850 yards wide and has generally decreasing depths of 180 to 72 ft.

4.3 PORT OLONGAPO COMPLEX

Port Olongapo consists of an outer harbor and an inner basin (see Figure 8). The port complex is approximately 1 1/2 miles wide between Cubi Point and Kalaklan Point and extends about 1 1/2 miles eastward to the coast. The inner basin lies between Maritan Point and Rivera Point, with the NSD terminal pier extending from its northeast shore. The shore is

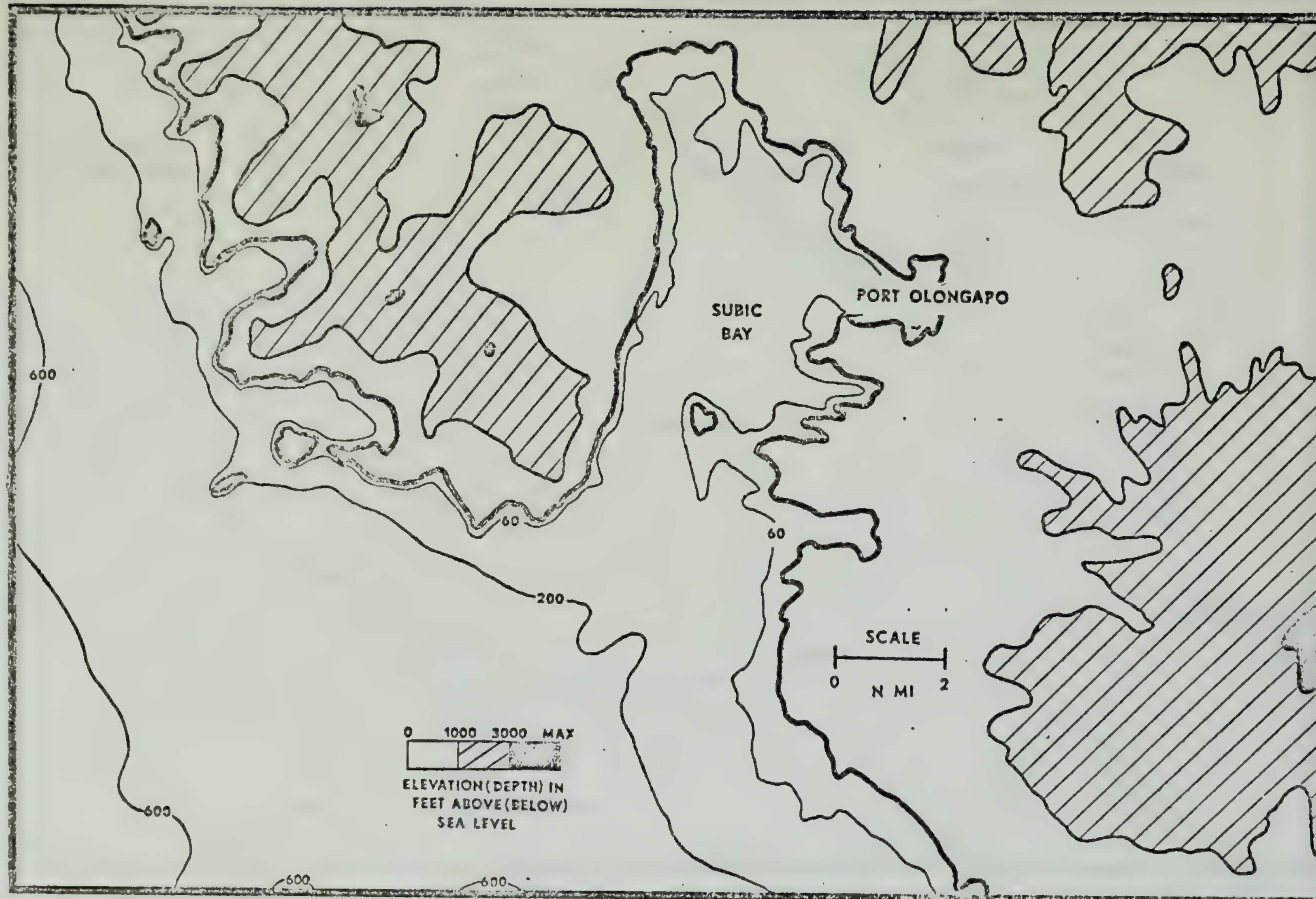

Figure 7. Map of the Subic Bay area showing topographical features of the surrounding terrain and bottom contours.

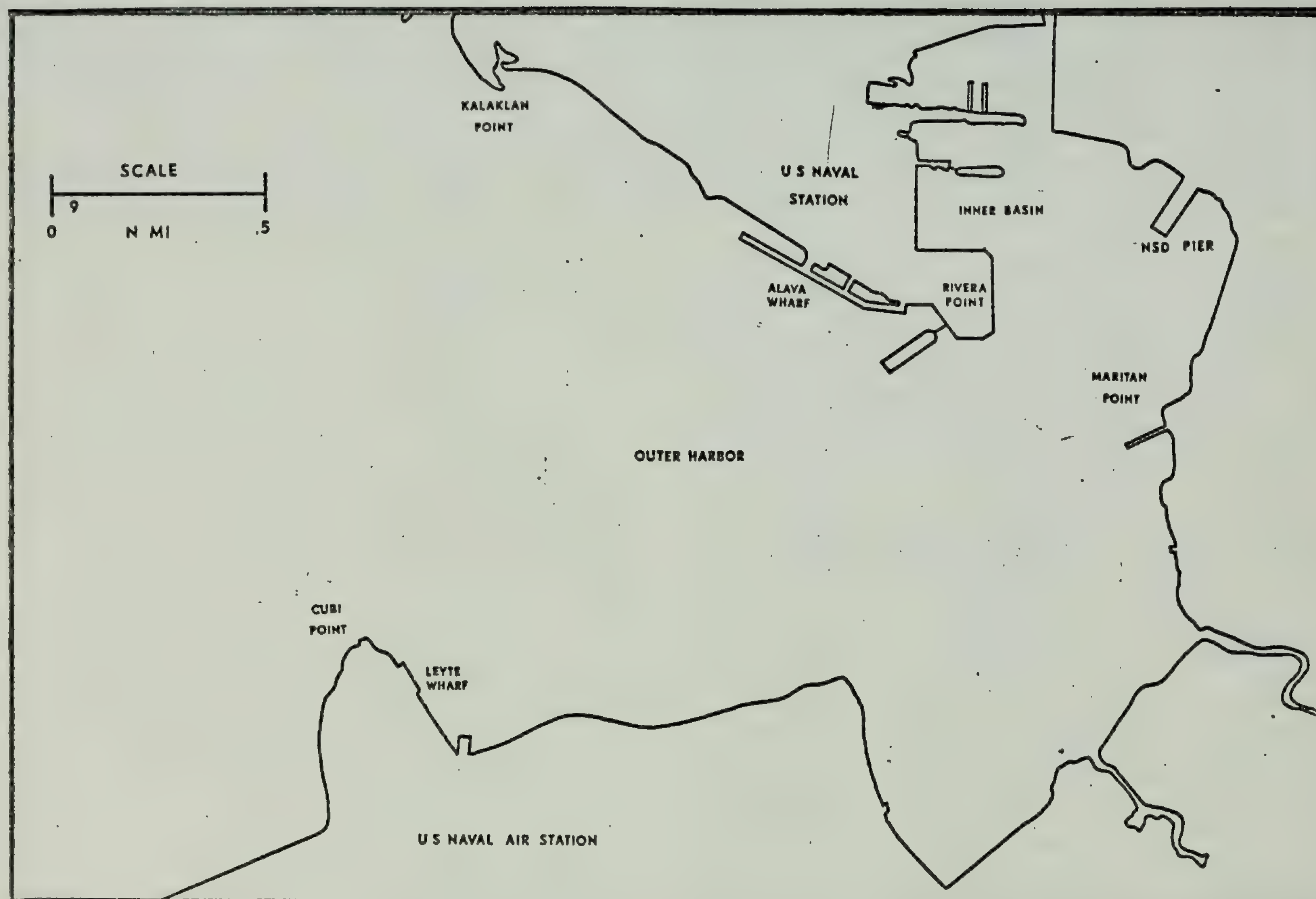

Figure 8. Port Olongapo showing the location of piers and wharves which are assigned to U.S. Navy ships.

extremely steep with liitle shoaling effect extending beyond a quarter mile offshore. Since Subic Bay is a U. S. Navy installation, all facilities are available for assignment to U. S. Navy vessels.

4.4 HARBOR FACILITIES

There are 6 wharves and 2 piers which serve as primary berthing spaces for vessels entering the Port Olongapo complex. Appendix C gives individual wharf and pier characteristics and facilities available. There are also 13 supplementary berths which are used for small craft only.

There are more than 160 safe anchorages in water depths of 70 to 150 ft with soft mud or coral bottom available in Subic Bay. Mooring buoys for all sizes of ships are available and assigned by the Port Operations Officer (H.O. Pub. No. 918, 1974).

5. TROPICAL CYCLONES AFFECTING SUBIC BAY

5.1 CLIMATOLOGY

Due to the extremely close proximity of Subic Bay to Manila Harbor, the two ports will not be considered separately with respect to the climatology of tropical cyclones. For the purposes of this study, the mid point (labeled point X in Figure 11) of a line connecting Manila Harbor and Port Olongapo was used. Point X is the center of a 180 n mi circle used to determine whether or not a tropical cyclone represents a threat (any tropical cyclone approaching within 180 n mi of point X is considered a threat) to the ports of Manila and Subic Bay. It is recognized that a few storms which did not approach within 180 n mi may have affected either or both ports. However, a reasonable criterion had to be chosen that would limit the size of the data sample.

Although tropical cyclones can occur at any time of the year, the majority of those that threaten Subic Bay and Manila occur during the months of June through December. Figure 9 depicts the monthly summary by 5-day periods of tropical cyclone occurrences based on data for the 19 years, 1955-1973. Of the 83 tropical cyclones that threatened Subic Bay and Manila, the peak threat periods exist in July, October, and November, but a consistent threat exists throughout the total June-December period.

Figure 10 displays the above storms as a function of the compass octant from which they approached point X. The numbers indicate the number of storms approaching from that octant, while the numbers in parentheses indicate the percentage of storms approaching point X from that octant. It is evident that the majority of storms approach Subic Bay and Manila from the east-southeast.

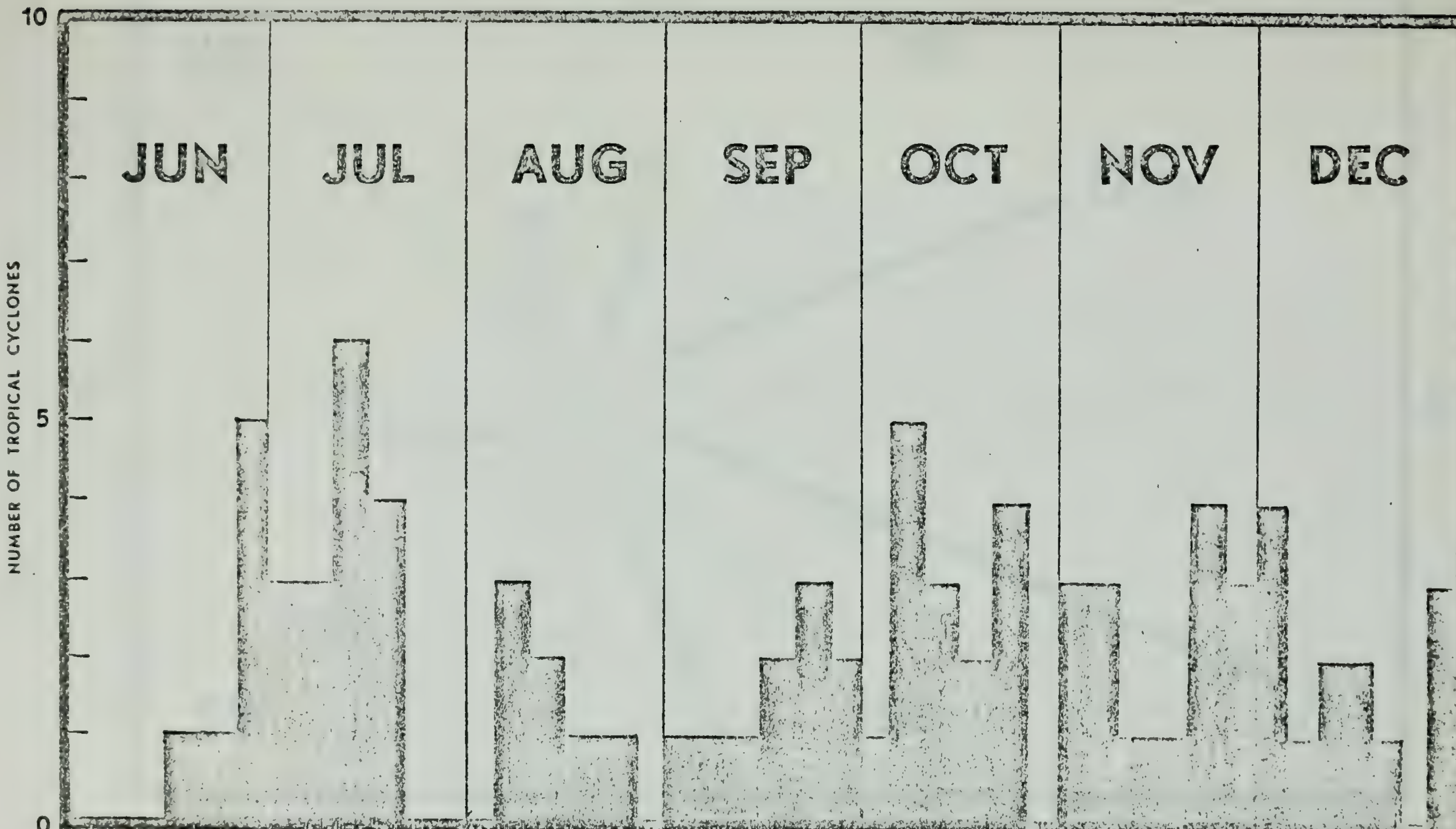

Figure 9. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of point X. Subtotals are based on 5-day periods, for tropical cyclones that occurred during 1955-1973.

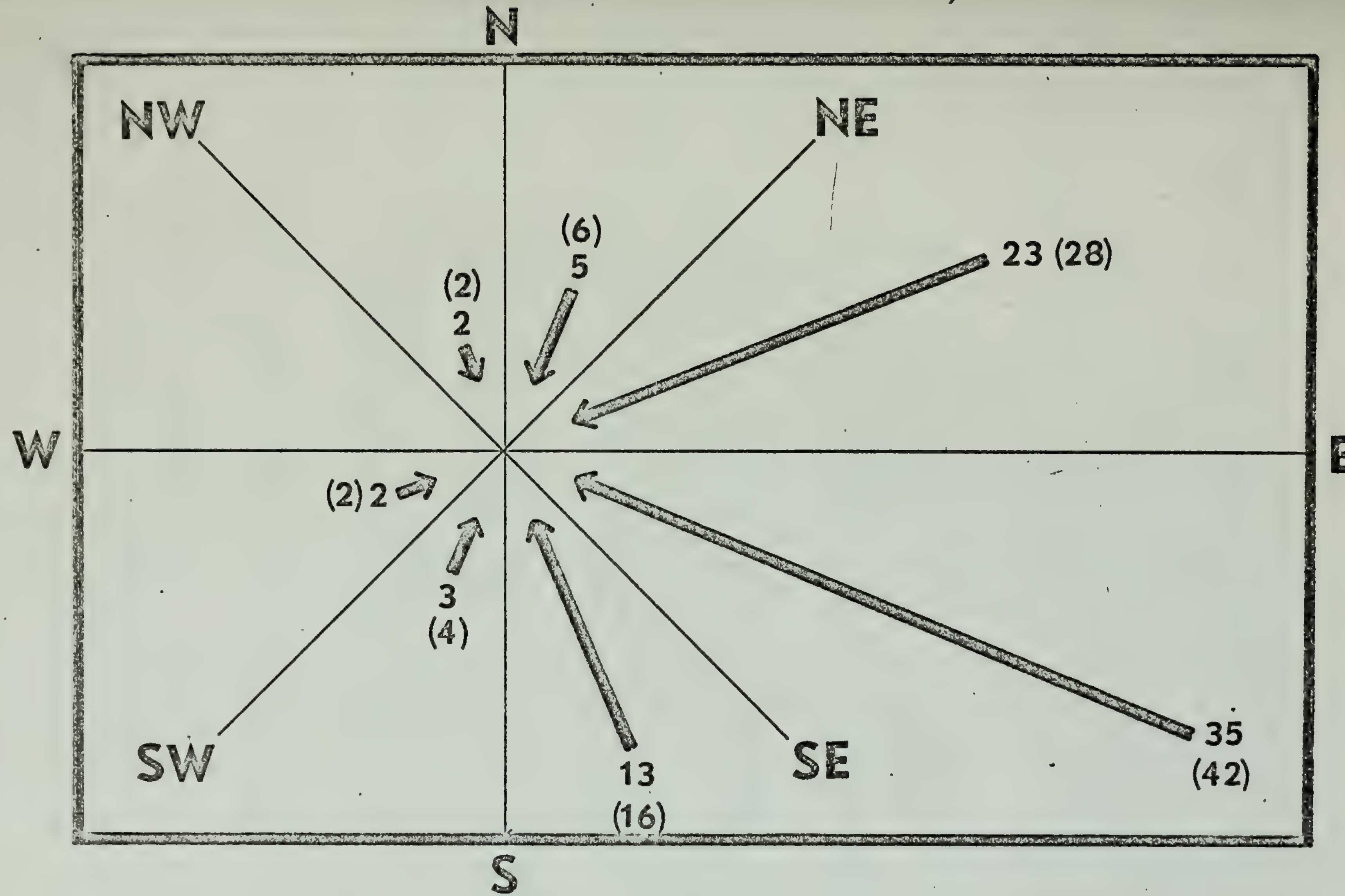

Figure 10. Direction of approach to point X of the tropical cyclones (1955-1973) that passed within 180 n mi of point X. Numbers indicate the number that approached from each octant. Number in parentheses is the percentage of the total sample (83) that approached from that octant.

An overall statistical summary of the tropical cyclone climatology of Subic Bay and Manila for the years 1884-1970 is provided by Figures 11 to 17 (based on data from Chin, 1972). This summary is based on tropical cyclone tracks grouped by months, June through December. Exact calendar months could not be used because the tracks were recorded for 5-day periods. To accurately assess the threat to Manila and Subic Bay, the following parameters were used:

- N - The total number of storms that passed through each 3° lat/long box for a given month,
- RAD - The percent of those tropical cyclones that passed through the box and passed within 180 n mi of point X,
- R_1 - Percentage of all tropical cyclones that passed through the box and crossed the line north of point X within a distance of 60 n mi (1° latitude),
- R_3 - Percentage of all tropical cyclones that passed through the box and crossed a line north of point X within a distance of 180 n mi (3° latitude),
- L_1 - Percentage of all tropical cyclones that passed through the box and crossed a line south of point X within a distance of 60 n mi (1° latitude),
- L_3 - Percentage of all tropical cyclones that passed through the box and crossed a line south of point X within a distance of 180 n mi (3° latitude).

N and RAD are printed on the top and bottom of the box, respectively. The others are printed at the left and right edges of the box.

For example, in Figure 11, the 3° square located between 129E and 132E, 9N and 12N had 8 tropical cyclones pass through it during the years 1884-1970. Of these, 63% approached within 180 n mi of point X, 13% passing within 60 n mi to the south and 25% within 180 n mi to the south; no storms passed within 60 n mi to the north and 25% within 180 n mi to the north.

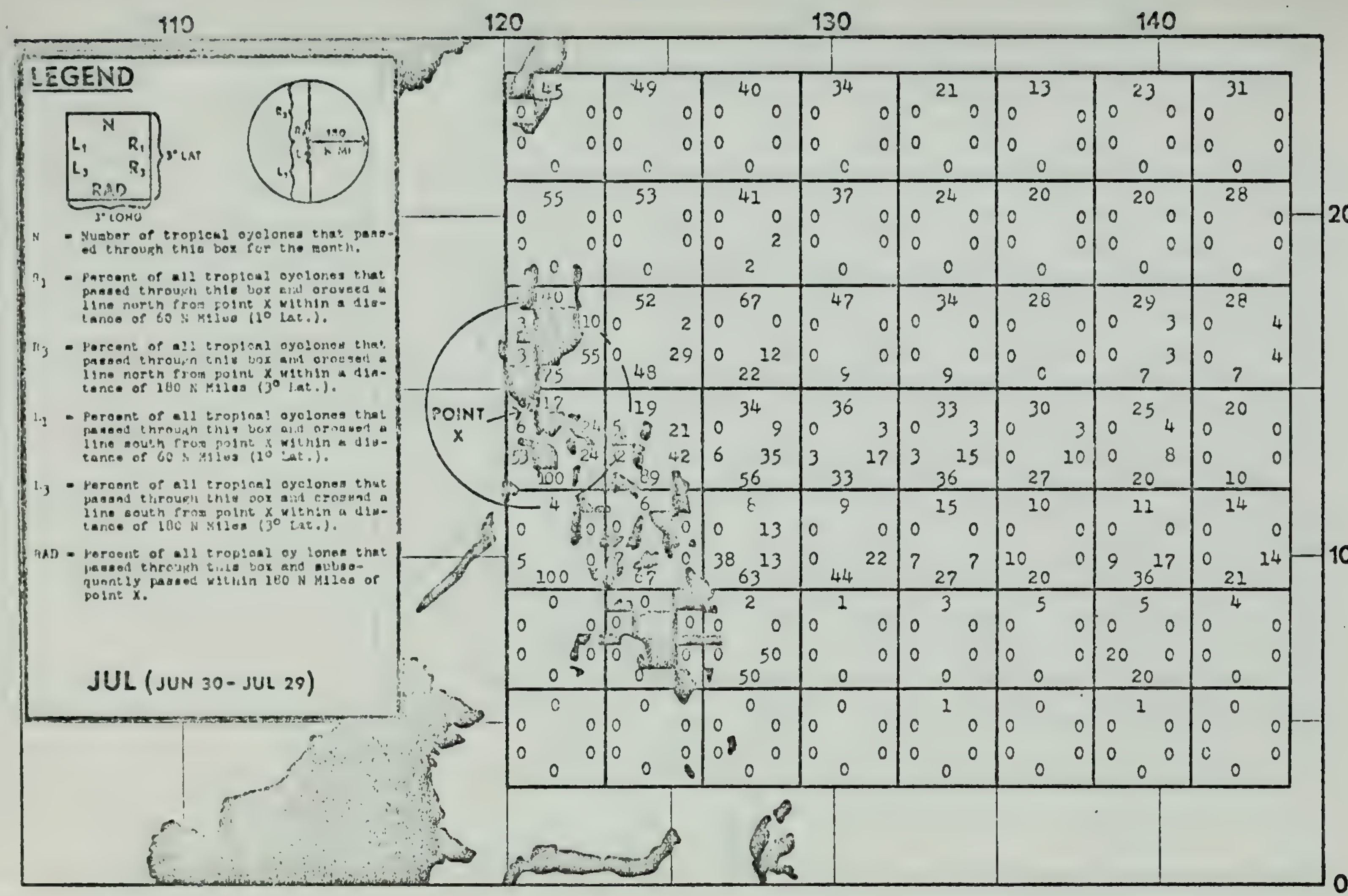

Figure 12. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of July. (Based on data from Chin (1972) for the years 1884-1970.)

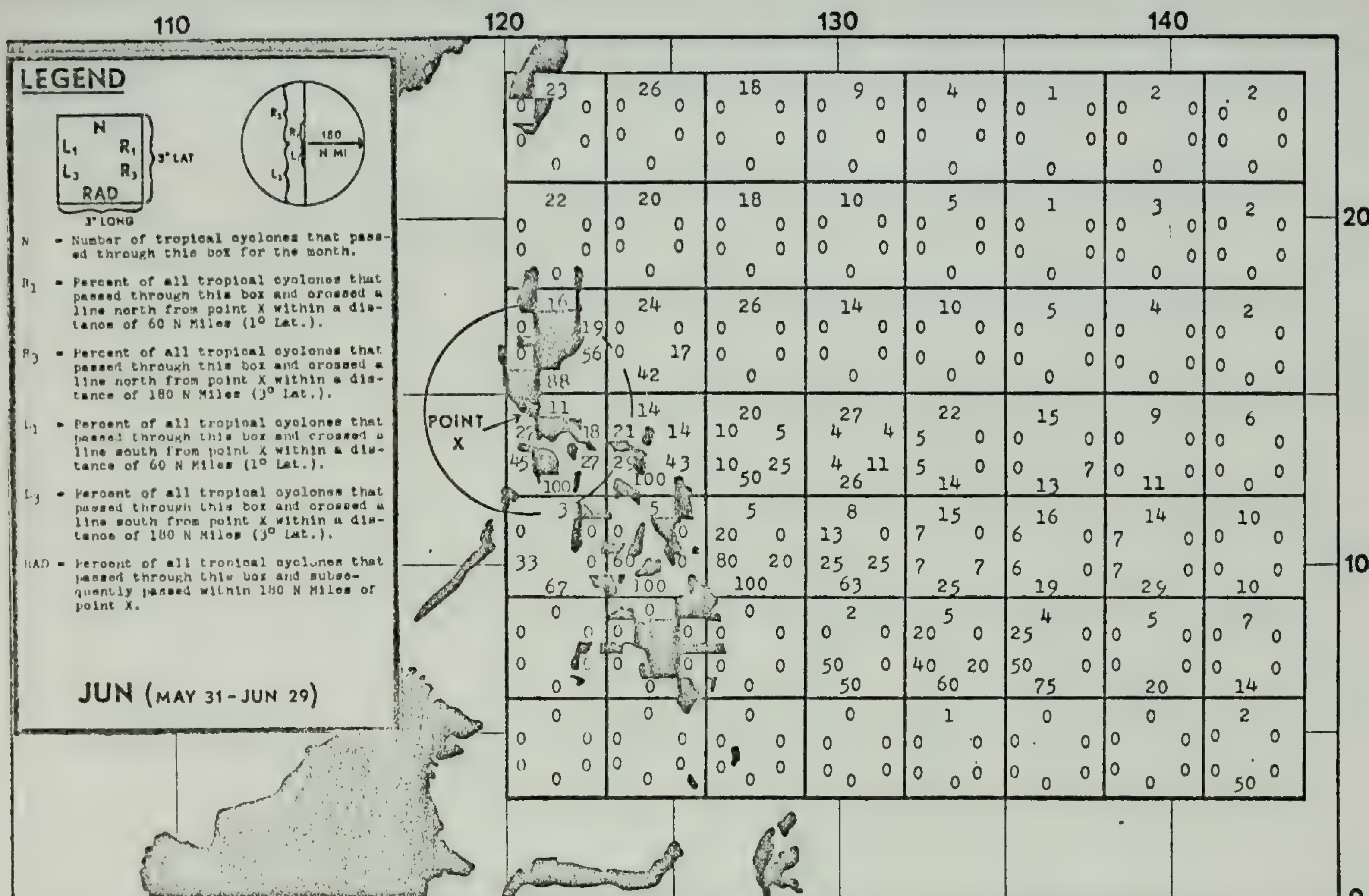

Figure 11. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of June. (Based on data from Chin (1972) for the years 1884-1970.)

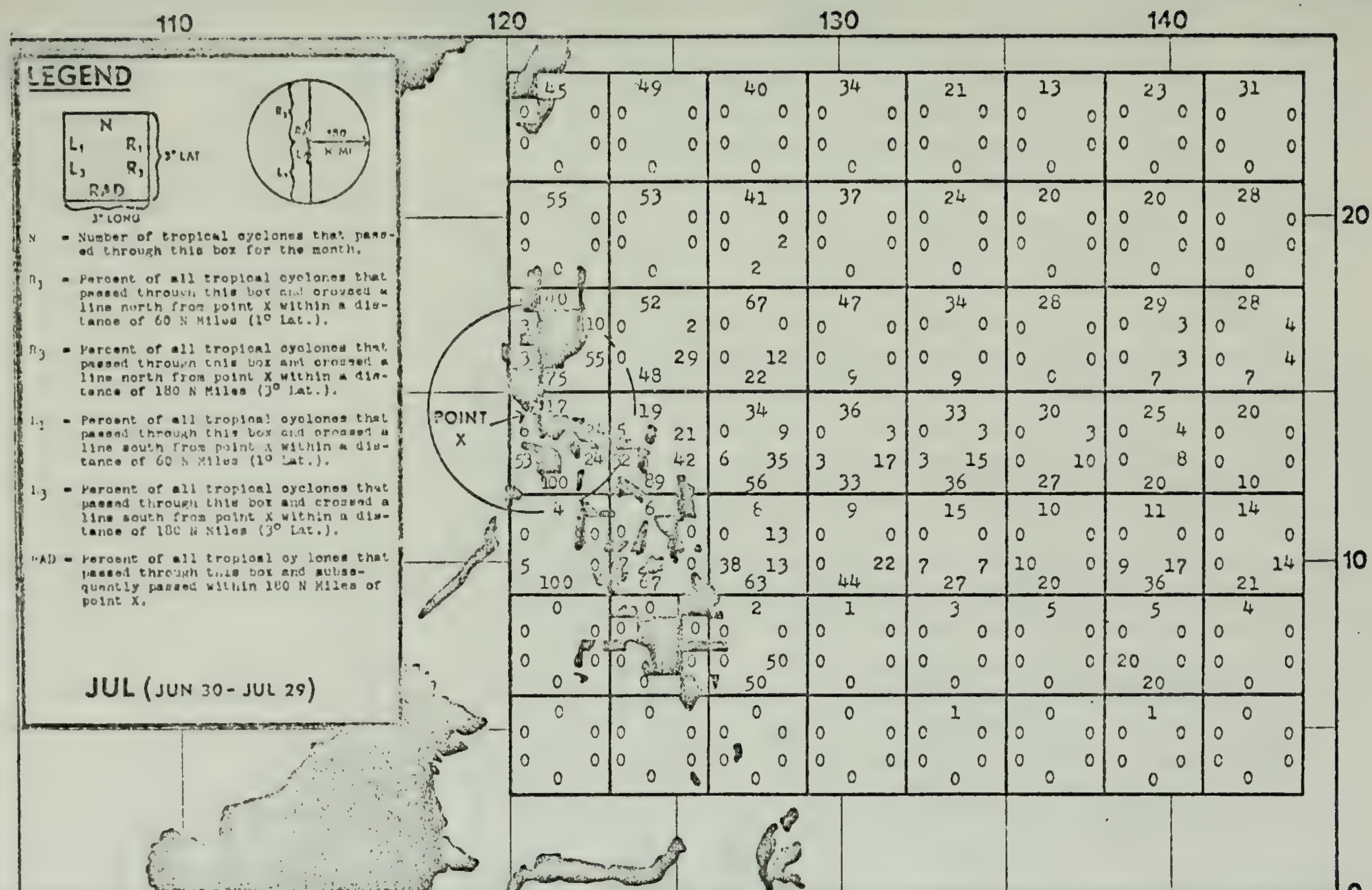

Figure 12. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of July. (Based on data from Chin (1972) for the years 1884-1970.)

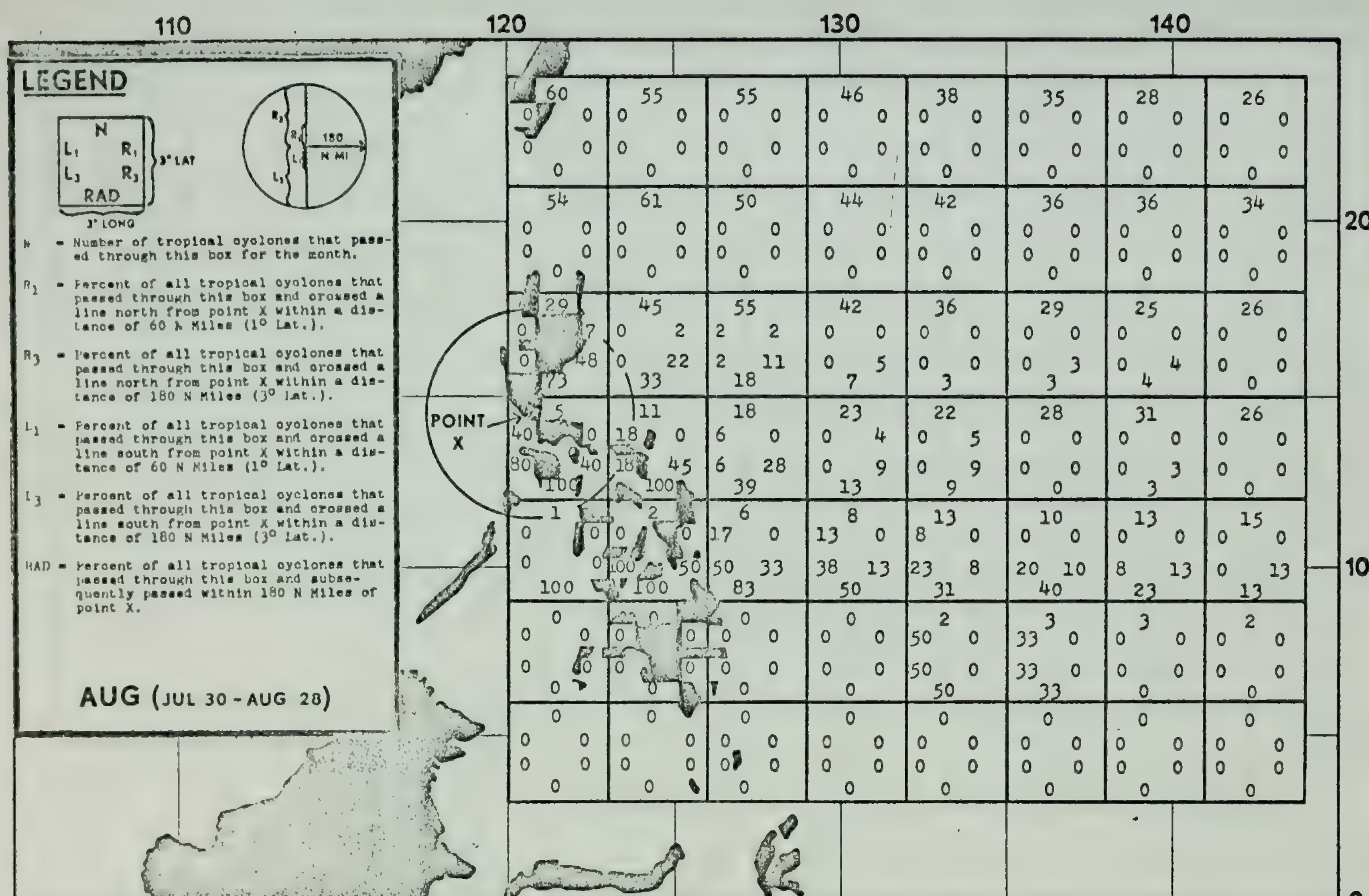

Figure 13. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of August. (Based on data from Chin (1972) for the years 1884-1970.)

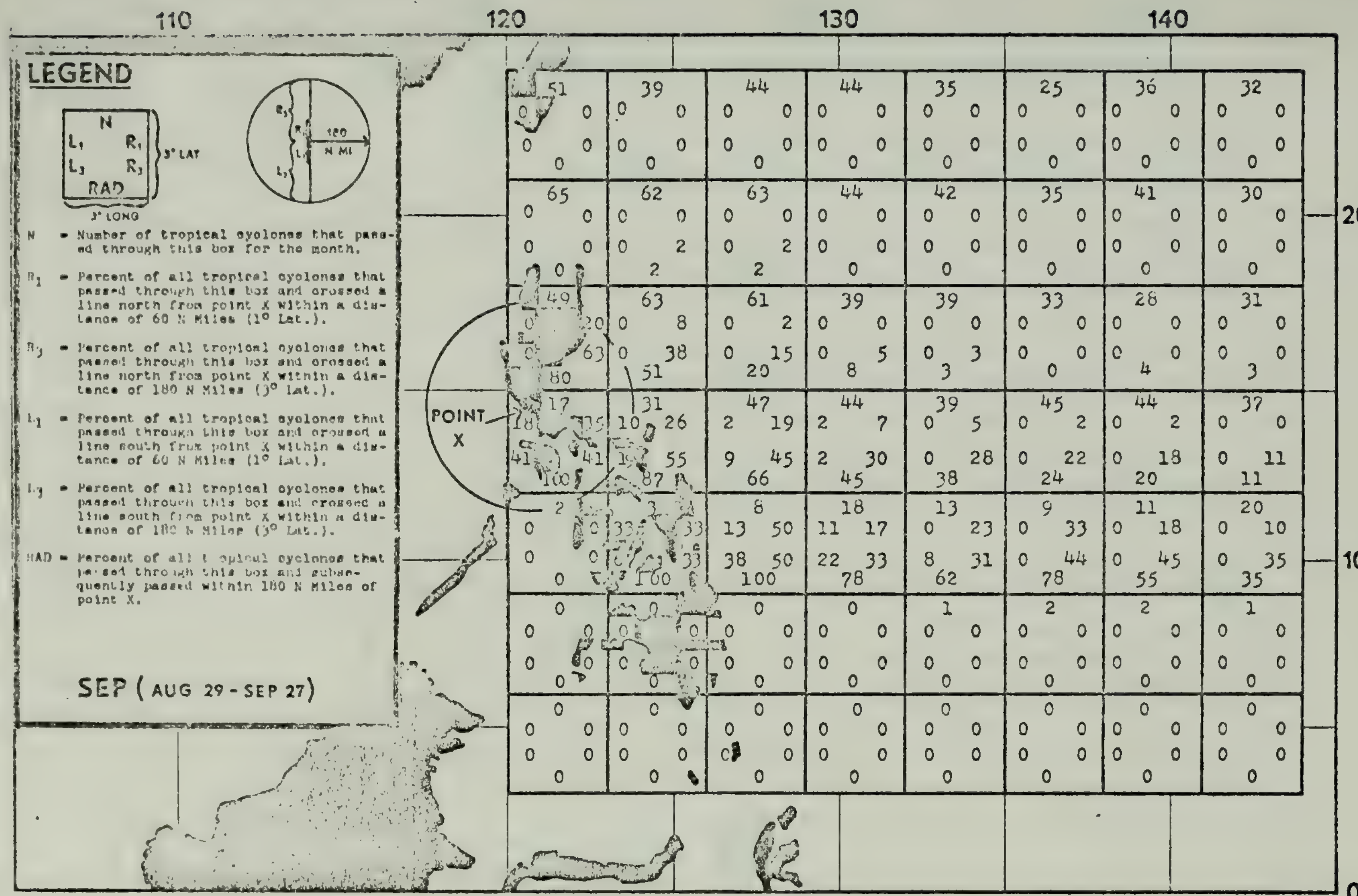

Figure 14. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of September. (Based on data from Chin (1972) for the years 1884-1970.)

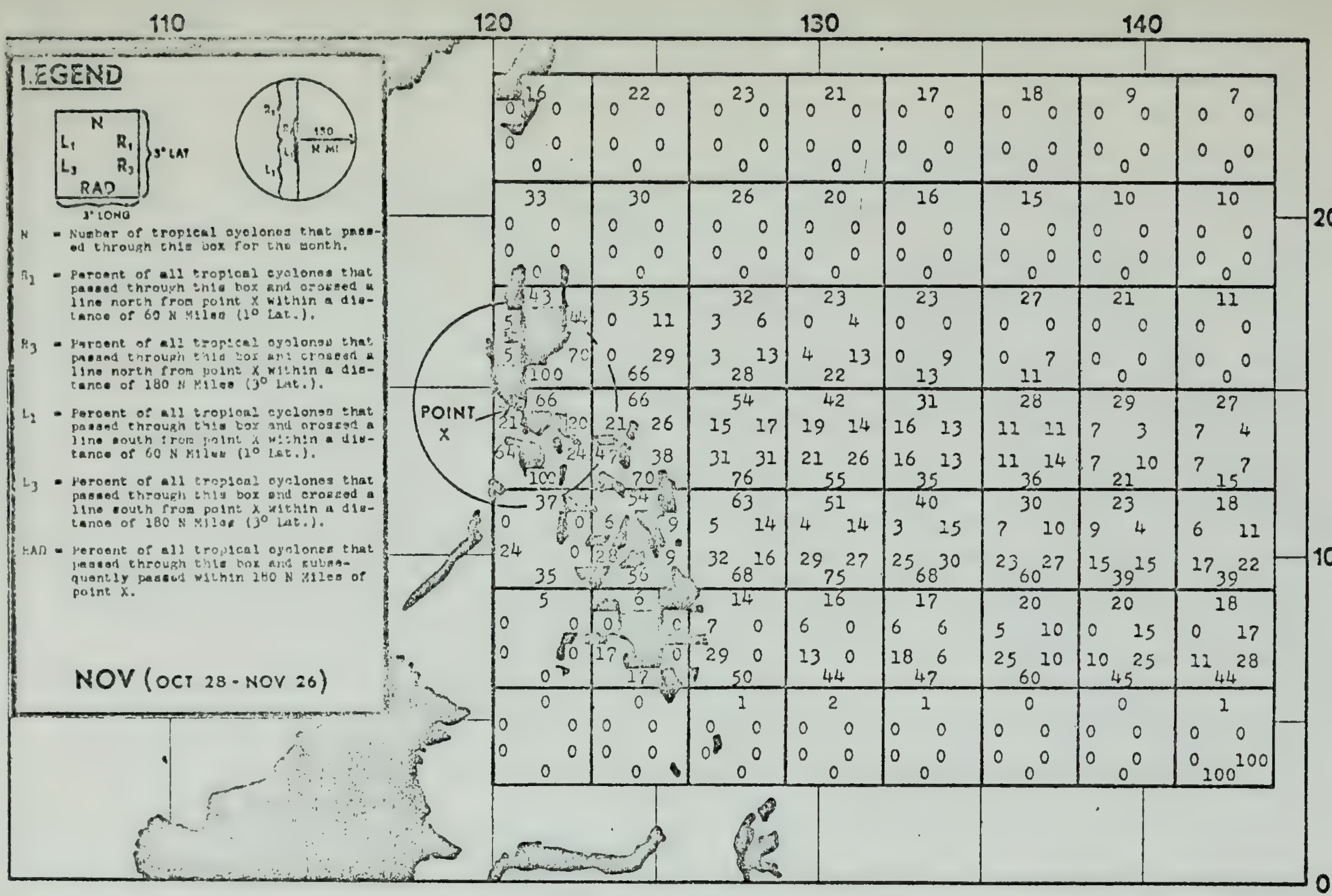

Figure 16. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of November. (Based on data from Chin (1972) for the years 1884-1970.)

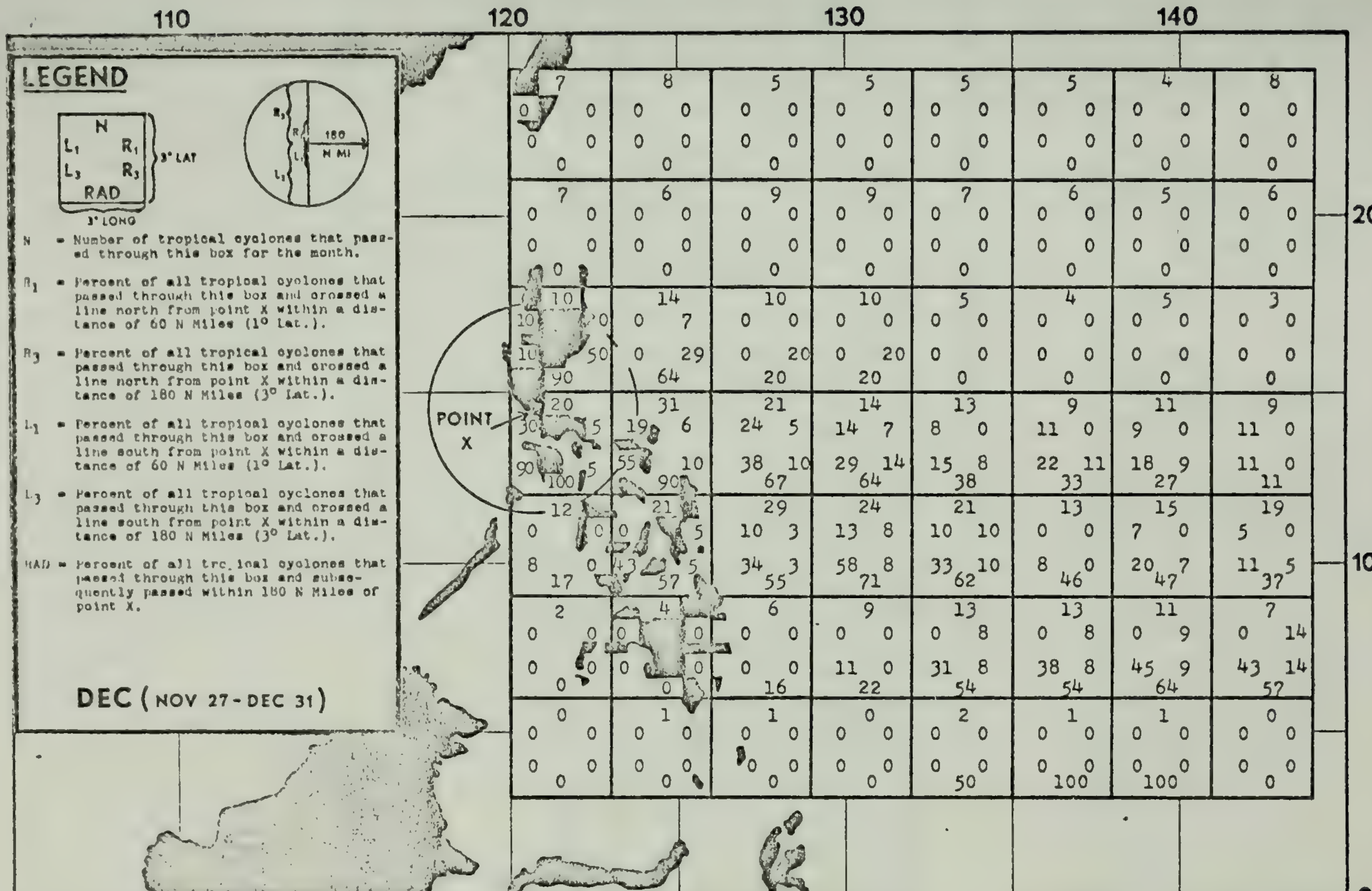

Figure 17. Statistical summary of tropical cyclone tracks that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of December. (Based on data from Chin (1972) for the years 1884-1970.)

Figures 18 to 24 represent an analyses of the RAD numbers from the above figures. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to point X based on an approach speed of 8-12 kt. For example, in Figure 18, a storm located at 130E and 10N has between a 60% and 80% probability of passing within 180 n mi of point X and it will reach point X in approximately 2 1/2 days if its speed remains within 8-12 kt.

5.2 WIND AND TOPOGRAPHICAL EFFECTS

In the 19 year period from 1955-1973, during the months June-December, a total of 83 tropical cyclones approached within 180 n mi of Subic Bay, which is more than four tropical cyclones per year.[4] The largest number of tropical cyclones to threaten Subic Bay in any single year was 11 in 1964. Table 1 groups the above 83 tropical cyclones according to the wind intensity that they produced at Subic Bay.[5] Of the 83 tropical cyclones concerned, 36% resulted in strong winds ($\geq$22 kt) and only 13% resulted in gale force winds ($\geq$34 kt).

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[4]From Chin (1972) for years 1955-1970 and from Annual Typhoon Reports for years 1971-1973 (U.S. FWC/JTWC, 1971-1973).

[5]Wind data are from Naval Air Station, Cubi Point, but are not continuous for years 1955-1957 since wind observations were made only during station operating hours. The data are considered representative of the winds in Subic Bay in most instances. The possibility does exist that winds from the southeast quadrant, due to the surrounding terrain, will indicate a lower velocity at Cubi Point than that experienced in the bay. It should be pointed out that because of the surrounding terrain around the Subic Bay area, it is very difficult to find a recording spot truly representative of the area.

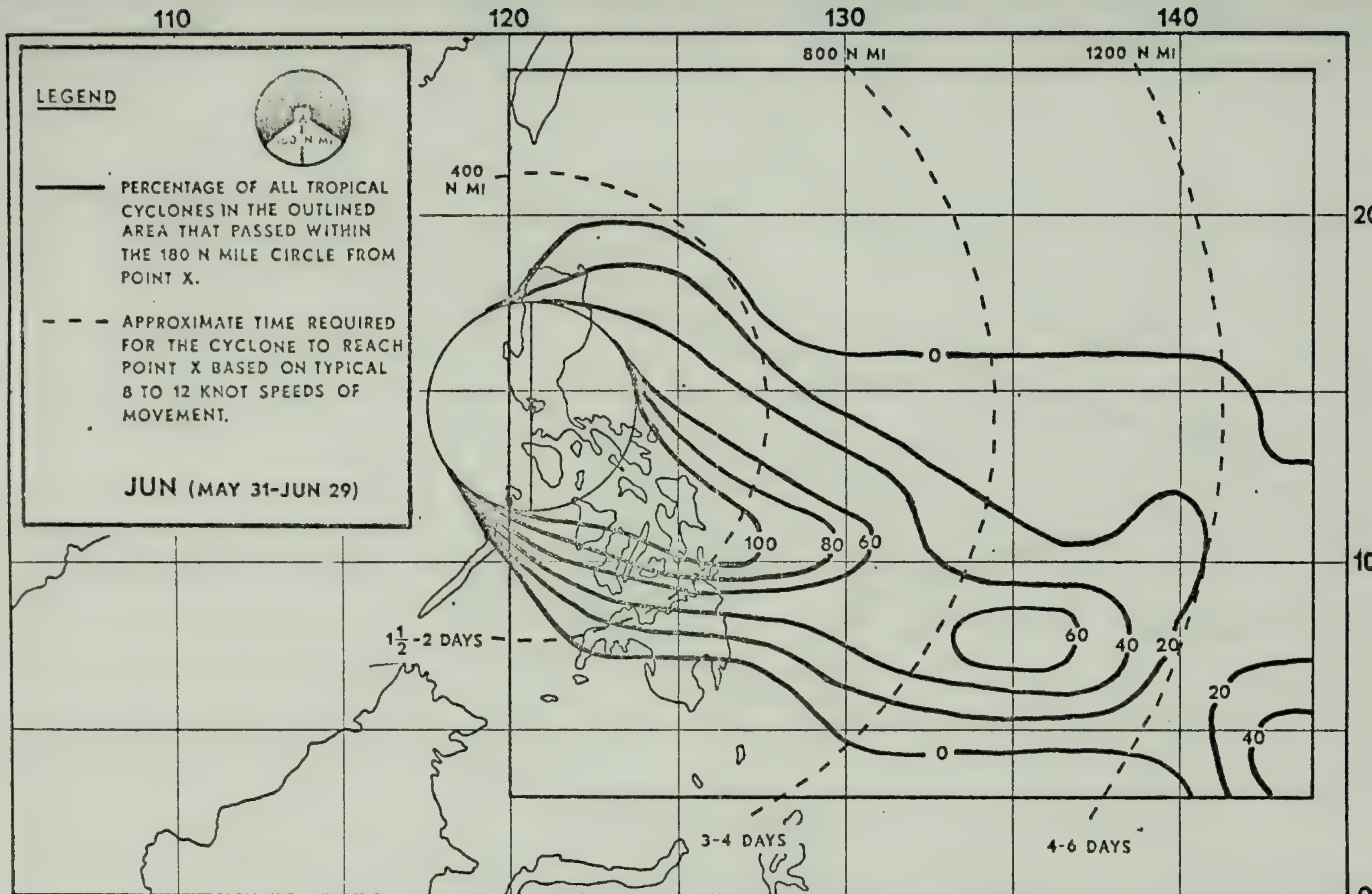

Figure 18. Percentage of tropical cyclones that passed within 180 n mi of point X (the midpoint of a line connecting Manila Harbor and Port Olongapo) for the month of June. (Based on data from Chin (1972) for the years 1884-1970.)

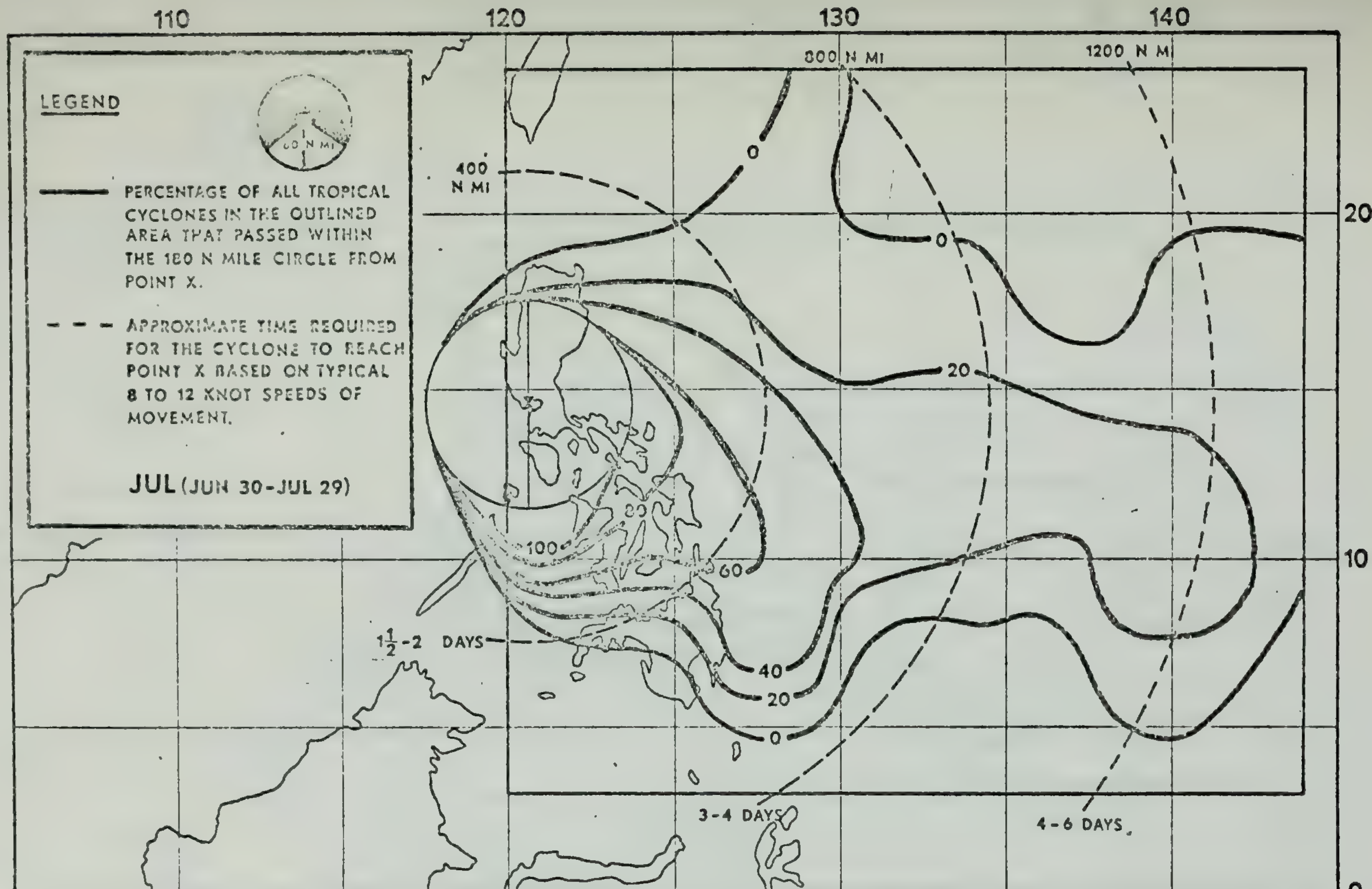

Figure 19. Percentage of tropical cyclones that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of July. (Based on data from Chin (1972) for the years 1884-1970.)

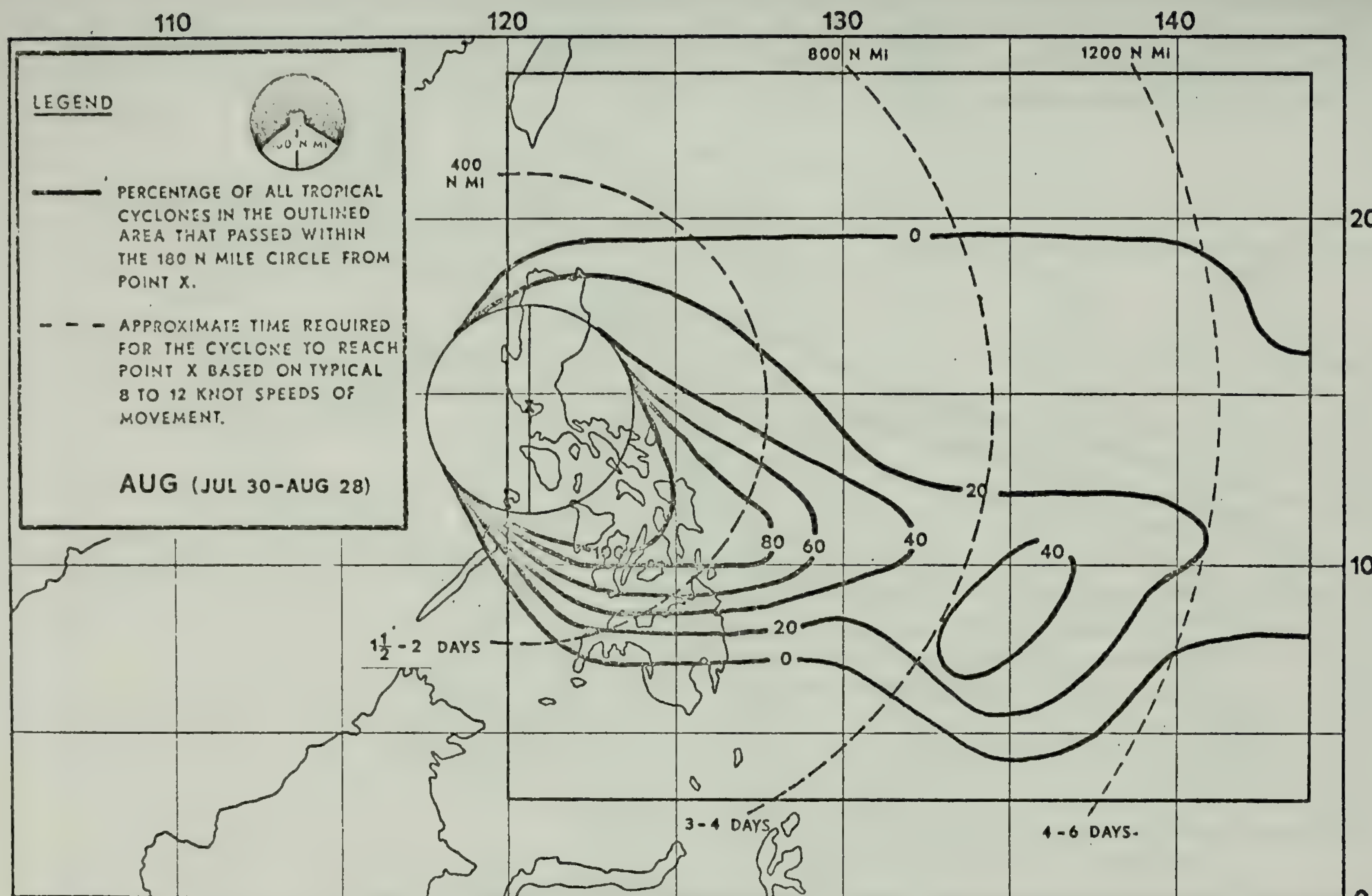

Figure 20. Percentage of tropical cyclones that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of August. (Based on data from Chin (1972) for the years 1884-1970.)

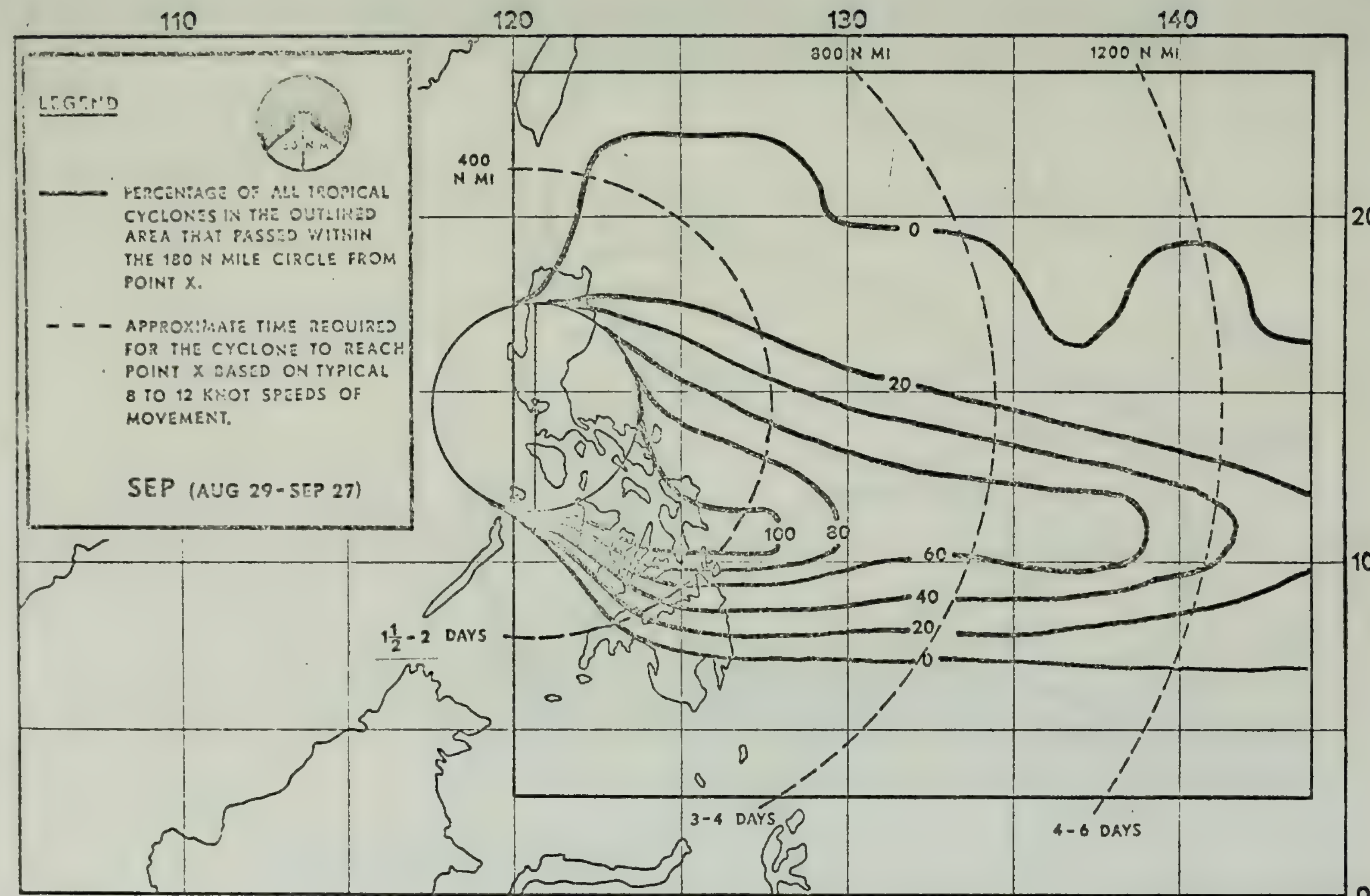

Figure 21. Percentage of tropical cyclones that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of September. (Based on data from Chin (1972) for the years 1884-1970.)

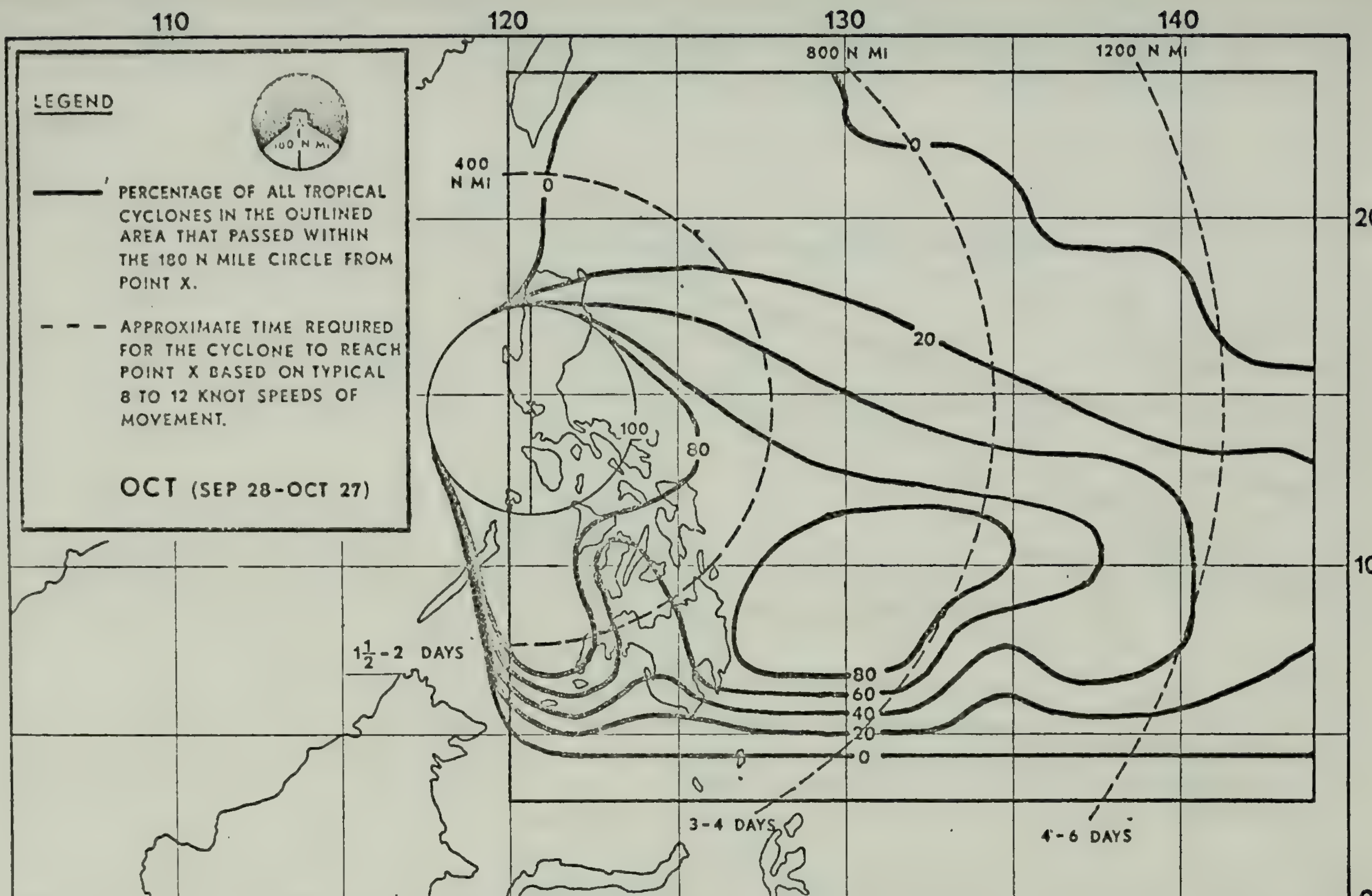

Figure 22. Percentage of tropical cyclones that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of October. (Based on data from Chin (1972) for the years 1884-1970.)

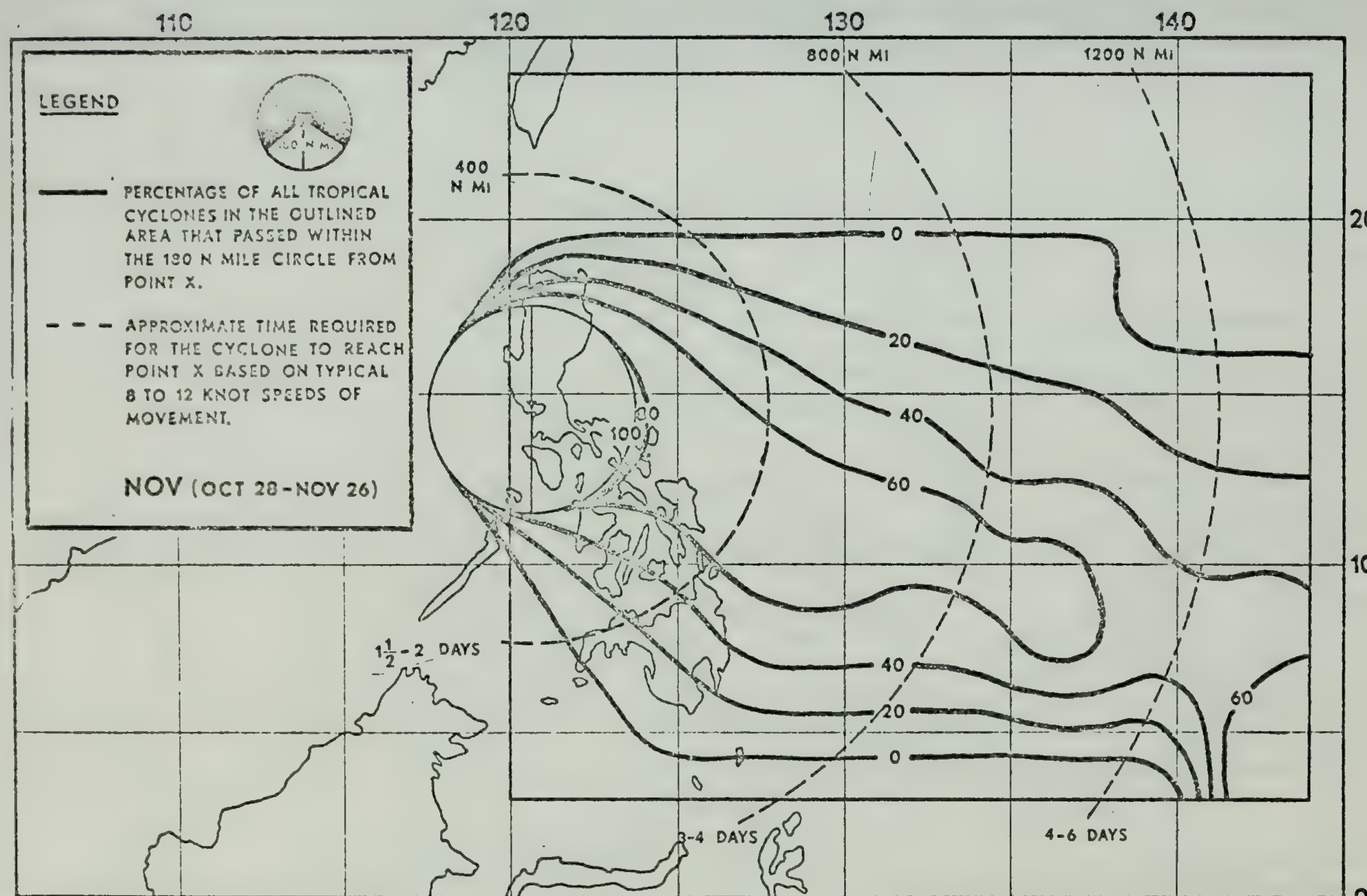

Figure 23. Percentage of tropical cyclones that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of November. (Based on data from Chin (1972) for the years 1884-1970.)

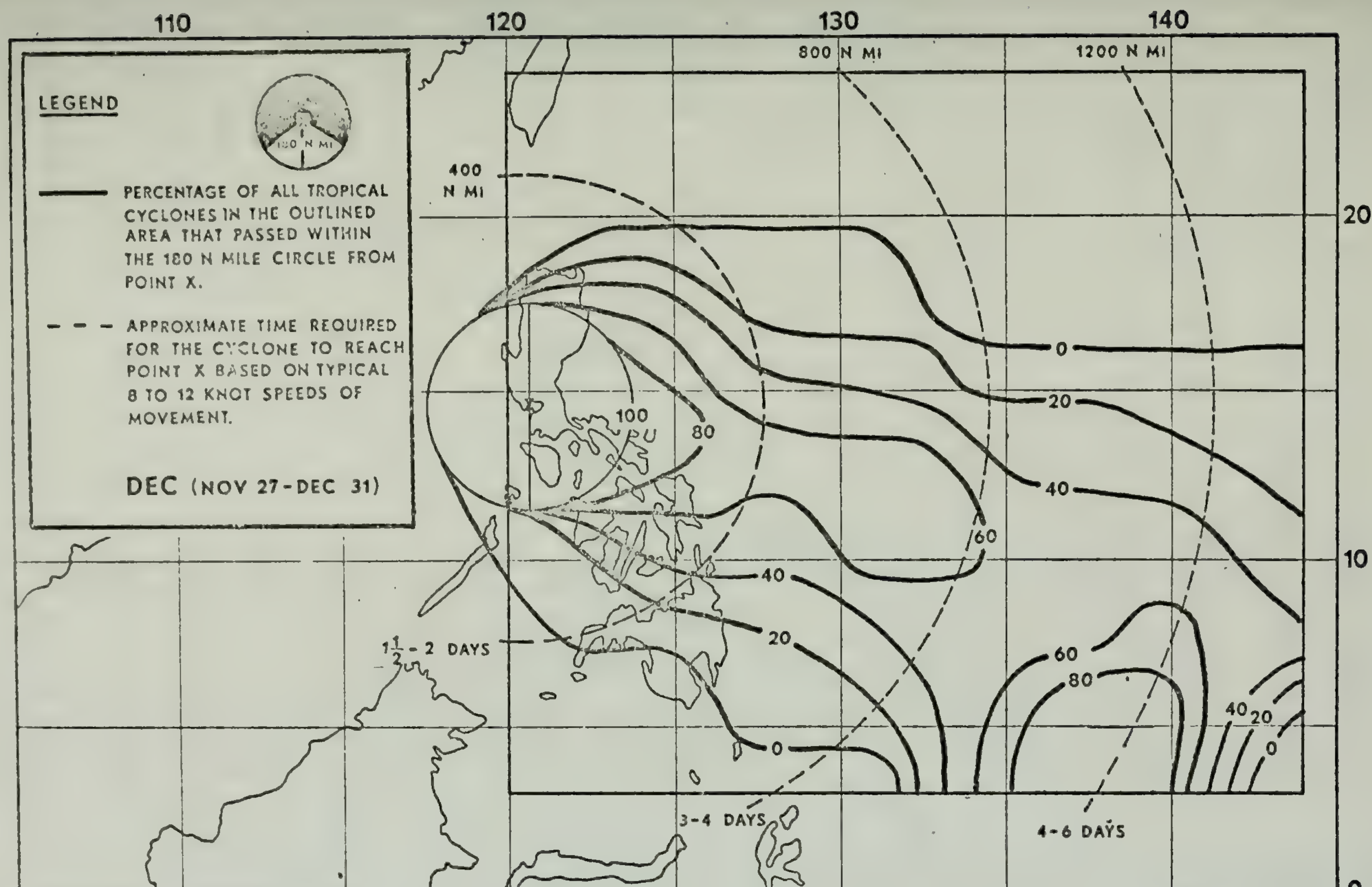

Figure 24. Percentage of tropical cyclones that passed within 180 n mi of point X (the mid point of a line connecting Manila Harbor and Port Olongapo) for the month of December. (Based on data from Chin (1972) for the years 1884-1970.)

Table 1. Extent to which tropical cyclones affected Subic Bay during the period June-December, 1955-1973.

Number of tropical cyclones that passed within 180 n mi of Subic Bay	83
Number of tropical cyclones resulting in strong ($\geq$22 kt) winds at Subic Bay	30
Number of tropical cyclones resulting in gale force ($\geq$34 kt) winds at Subic Bay	11

It is apparent from the results of Table 1 that Subic Bay is a sheltered harbor. This sheltering effect provided by the terrain surrounding Subic Bay is depicted in Figure 7. The mountains surrounding Subic Bay serve as an effective wind barrier and are the reason that 56 kt is the highest sustained wind recorded there during the years 1955-1973.

Figures 25 and 26 depict the tracks for the months June through December of tropical cyclones occurring during the period 1955-1973 that resulted in gale force winds at Subic Bay. From this orientation and a comparison with the percent threat figures in the preceding section, it is evident that tropical cyclones approaching from the southeast and east and passing, in general, to the north represent the primary threat to Subic Bay.

The arrows showing tropical cyclone movement in Figure 27 give the positions of tropical cyclone centers when the wind first and last exceeded 22 kt at Subic Bay. Figure 28 shows the position of tropical cyclone centers when the wind first and last exceeded 34 kt. Note that in most cases the tropical cyclones that affected Subic Bay with winds exceeding 22 kt passed to the north. In all instances, the onset of 22 kt winds did not occur until the tropical cyclones had approached within approximately 100 n mi of the eastern coast of the Philippines. On the other hand, tropical cyclones in the South China Sea more than 300 n mi from the west coast of the Philippines have produced 22 kt winds at Subic Bay. Note that

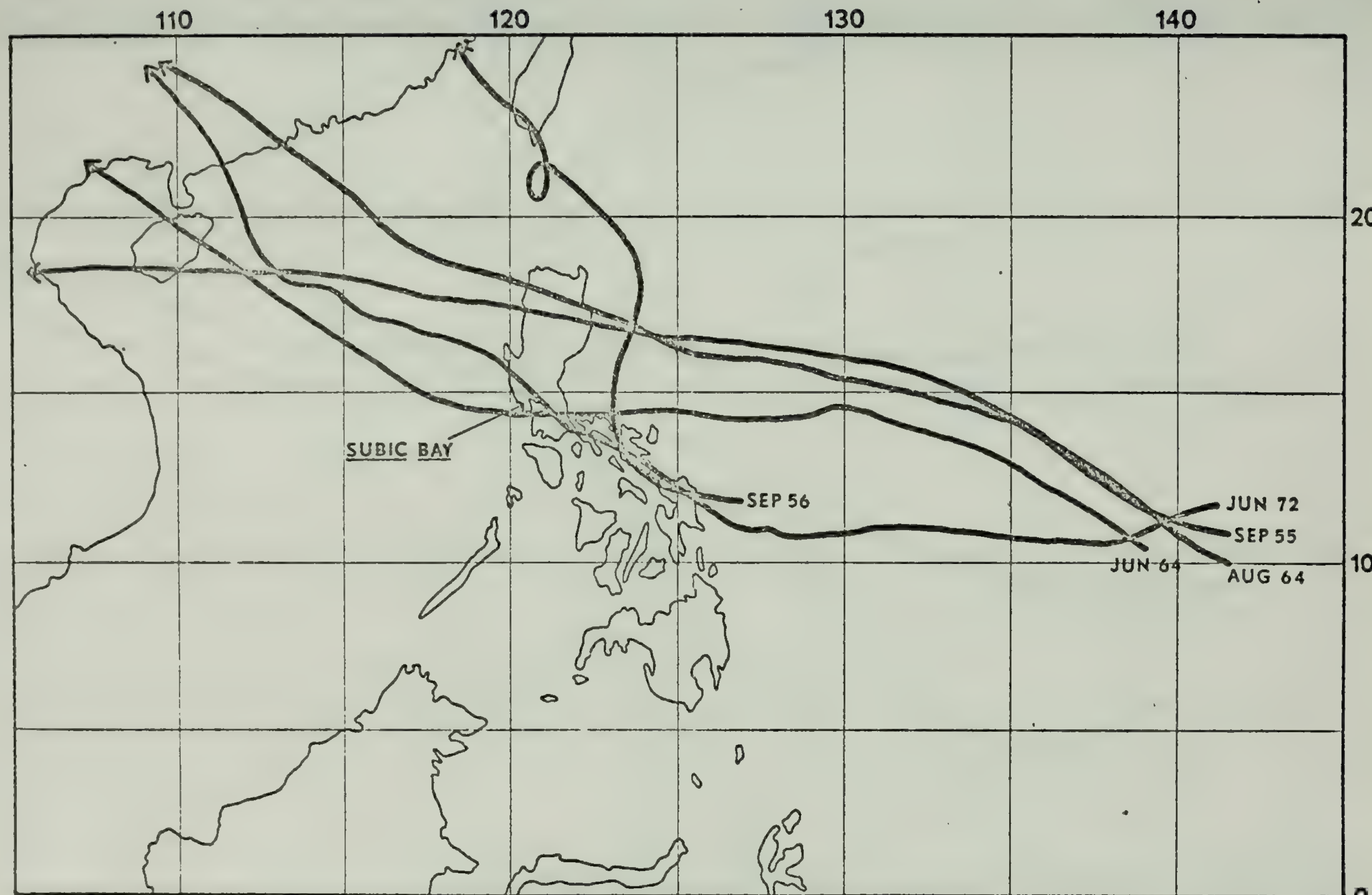

Figure 25. Tracks for tropical cyclones associated with gale force (or greater) winds at Subic Bay for the months June-August. (Based on data from 1955-1973.)

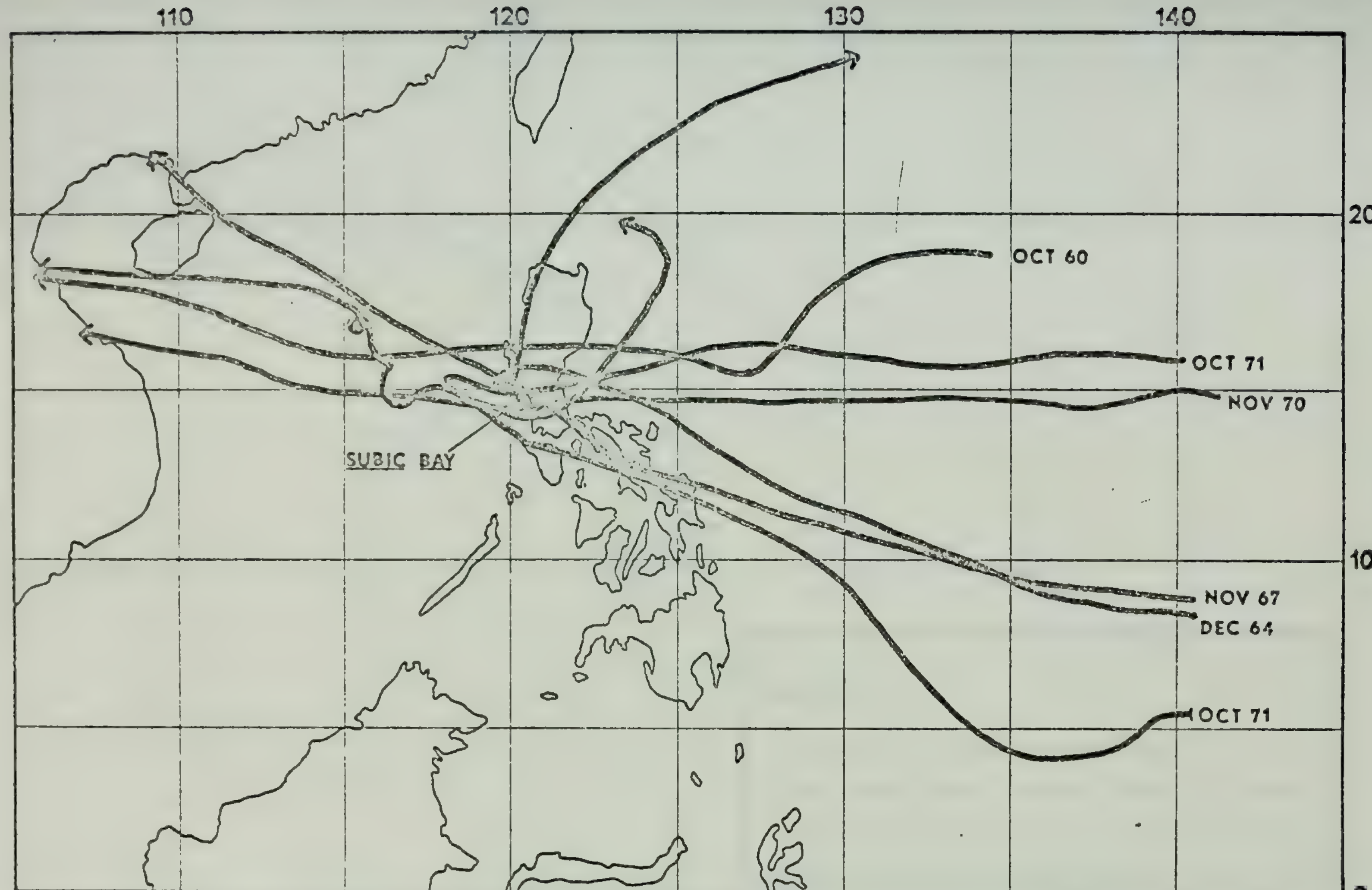

Figure 26. Tracks of tropical cyclones associated with gale force (or greater) winds at Subic Bay for the months September-December. (Based on data from 1955-1973.)

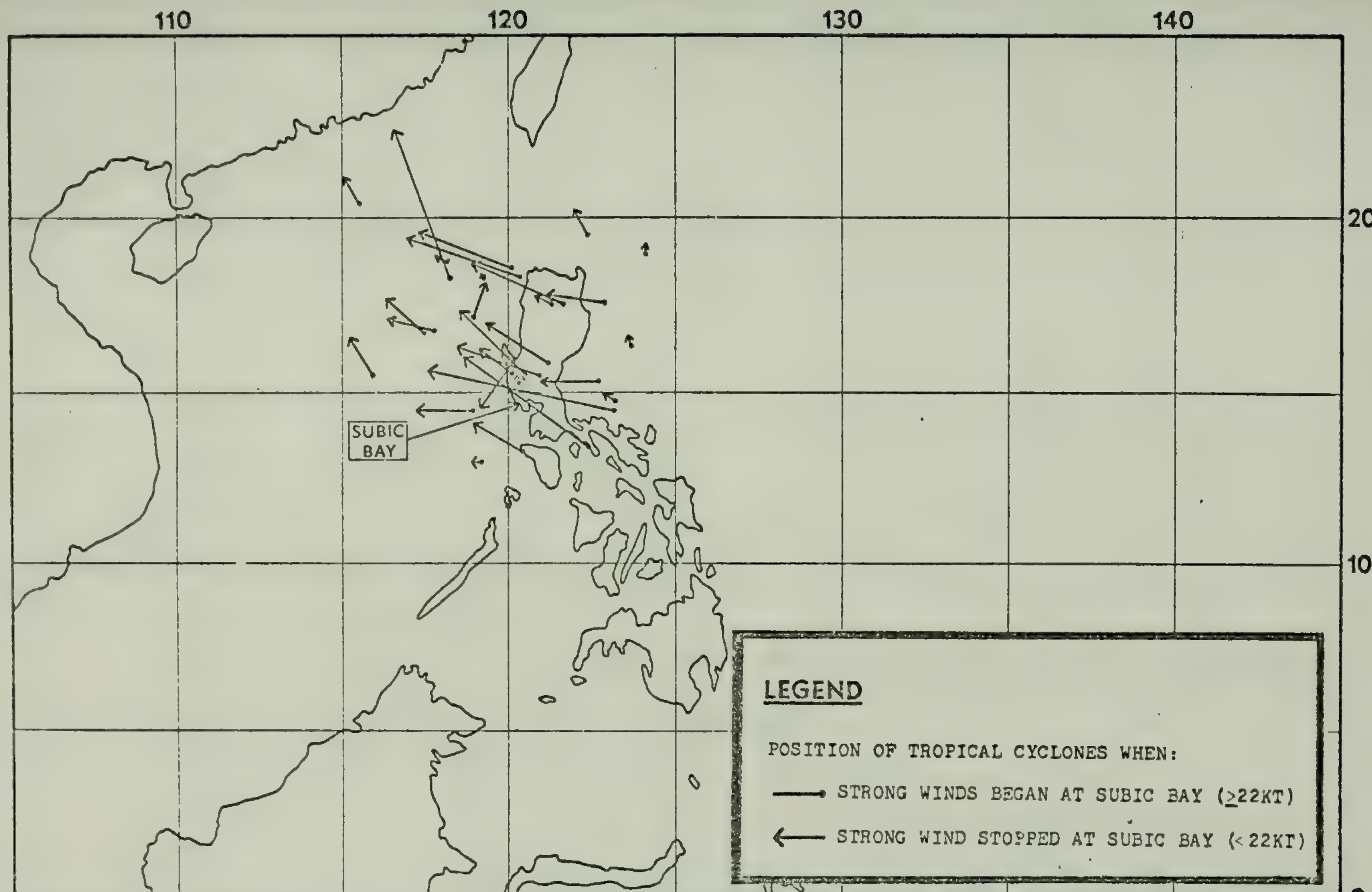

Figure 27. Positions of tropical cyclone centers when >22 kt winds first and last occurred at Subic Bay. (Based on data from 1955–1973.)

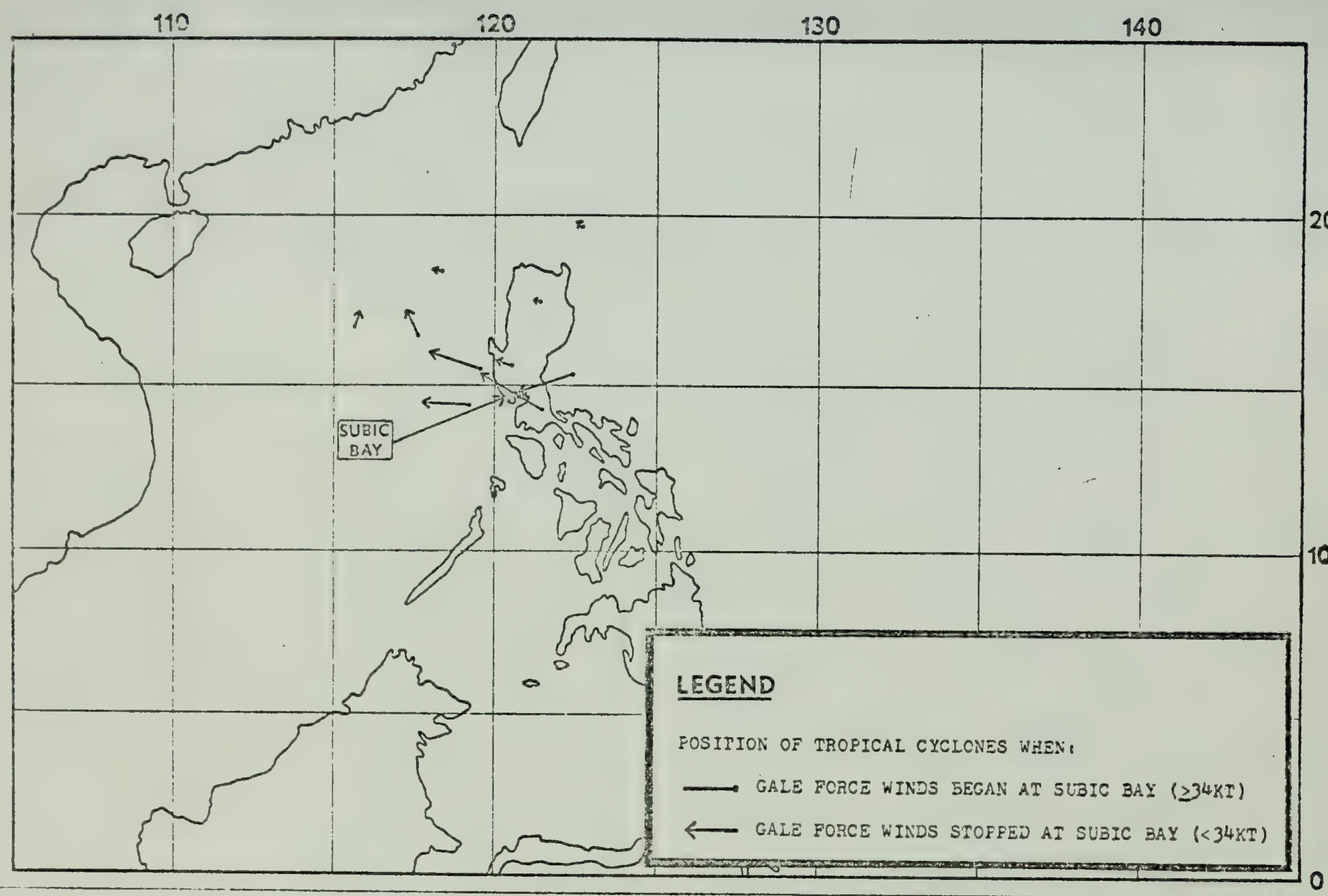

Figure 28. Positions of tropical cyclone centers when ≥ 34 kt winds first and last occurred at Subic Bay. (Based on data from 1955–1973.)

most strong wind occurrences exist with storms to the north and west of Subic Bay.

5.3 WAVE ACTION

The largest waves in the vicinity of Subic Bay occur just outside the entrance of the bay. Examination of available wave data revealed that southwest monsoonal winds and typhoons in the South China Sea are responsible for the high wave conditions at the entrance to Subic Bay. Another contributing factor is the hydrography in the area, the predominant feature being the relatively deep water close to the entrance of Subic Bay and the reefs along the shorelines (see Figure 7). Although no direct observations have been recorded at Subic Bay, computational estimates (Johnson and Wiegel, 1955) indicate that significant wave heights of 32 ft and periods of 12 seconds could occur at the entrance to Subic Bay with the close passage of an intense typhoon.

The interior of Subic Bay is protected from significant wave action by the geography of the area, the southwest orientation of the bay, and the nearby hydrography. Only waves from the southerly or westerly directions have any effect on the interior of Subic Bay. These waves enter the bay, but reach interior points only by refraction around the east or west sides of Grande Island, and are of little significance.

5.4 STORM SURGE AND TIDES

Examination of charts from a now defunct portable tide gage and conversations with engineers revealed no evidence of storm surge in Subic Bay (Johnson and Wiegel, 1955). Tidal currents in Subic Bay are variable and generally weak. Tides are predominantly diurnal, with a tidal range of 3.1 ft (average) and 6.0 ft (extreme).

6. PREPARATION FOR HEAVY WEATHER

6.1 TROPICAL CYCLONE WARNINGS

Tropical cyclone warnings, including 24-, 48-, and 72-hr forecasts, are supplied by the Fleet Weather Central/Joint Typhoon Warning Center (FWC/JTWC) located on Guam. COMSEVENTHFLT OPORD 201-(YR), Annex W, describes the procedures and techniques to be used when plotting the FWC/JTWC typhoon warning track positions. Figure 29 demonstrates these procedures, utilizing the 135 n mi average 24-hr forecast position error in obtaining the "danger area." This is necessary in order to expand the radius of 30-kt winds, given in the warning, by the average forecast error. Note the radius of 30-kt winds is usually greater on the right side of the storm track -- the dangerous semicircle. In this example, the radius to the 30-kt isotach is 200 n mi to the north and 150 n mi to the south. The 24-hr forecast predicts the radius to expand to 225 n mi to the north and 175 n mi to the south. Adding the average 24-hr forecast position error to the above figures forecasts a 24-hr danger area extending 360 n mi to the north and 310 n mi to the south. The 48- and 72-hr forecast positions given in the FWC/JTWC warning provide for a 275 n mi and 400 n mi average forecast error, respectively.

Section 6 of Appendix I to Annex W of COMNAVPHIL OPORD 201-72 discusses the criteria for setting local heavy weather readiness conditions and is reprinted in this study as Appendix D.

6.2 REMAINING IN PORT

Remaining in port when the means to evade a storm is available is a decision that is contrary to most of the traditional rules of seamanship. However, if the decision to remain in port is made, it should not be made without considering

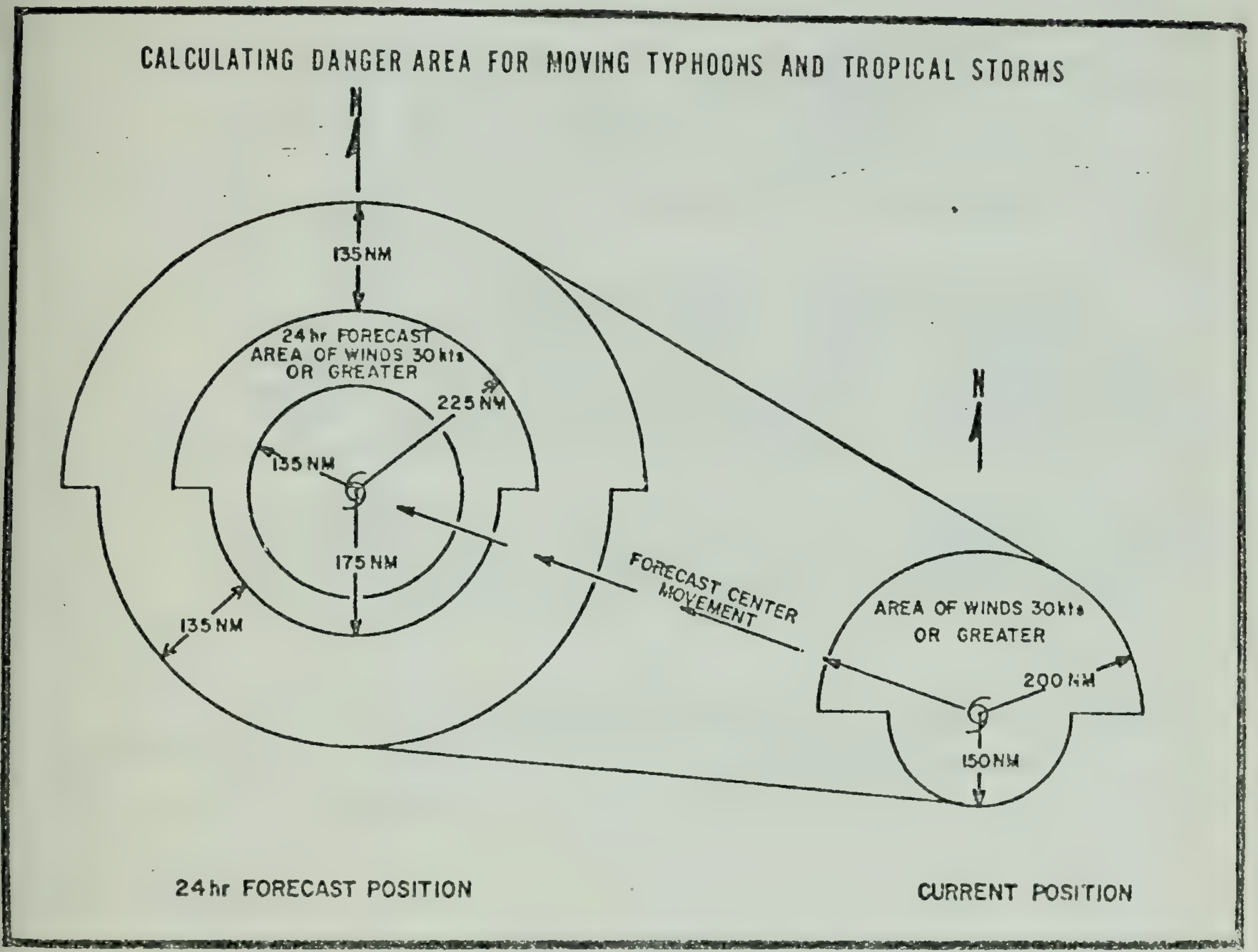

Figure 29. Method of calculating the danger area for moving typhoons and tropical storms (from Commander, Seventh Fleet, OPORD 201-YR).

every available fact concerning the impending storm and the port in which the vessel is berthed. In the case of Port Olongapo in Subic Bay the following points should be noted:

1. Securing to a pier or anchoring in the bay should be done prior to the onset of 20-kt winds to prevent undue difficulty in mooring.

2. No berths in Port Olongapo can be considered sheltered.

3. Once the decisions to remain in port has been made, any reversal in plans would be extremely dangerous. Subic Bay is a relatively sheltered harbor so any wave and wind actions experienced inside the bay would be greatly magnified outside the entrance to the bay and in the open sea.

4. The holding action of the mud and coral bottom is considered good and the danger of ships breaking loose in heavy weather is less in Subic Bay than in many other WESTPAC ports.

For a detailed, in depth account of conditions in Subic Bay during the passage of a typhoon, see the case study contained in Appendix F.

6.3 EVASION

When evasion of a tropical cyclone is being contemplated the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. The following time table, depicted in Figure 30 has been set up for this purpose:

I. An existing tropical cyclone, or potential development in area C with forecast movement toward Subic Bay:

   a. Review the material condition of the ship; sailing within 2-4 days is a distinct possibility.

   b. Reconsider all maintenance activities scheduled to exceed 48 hours.

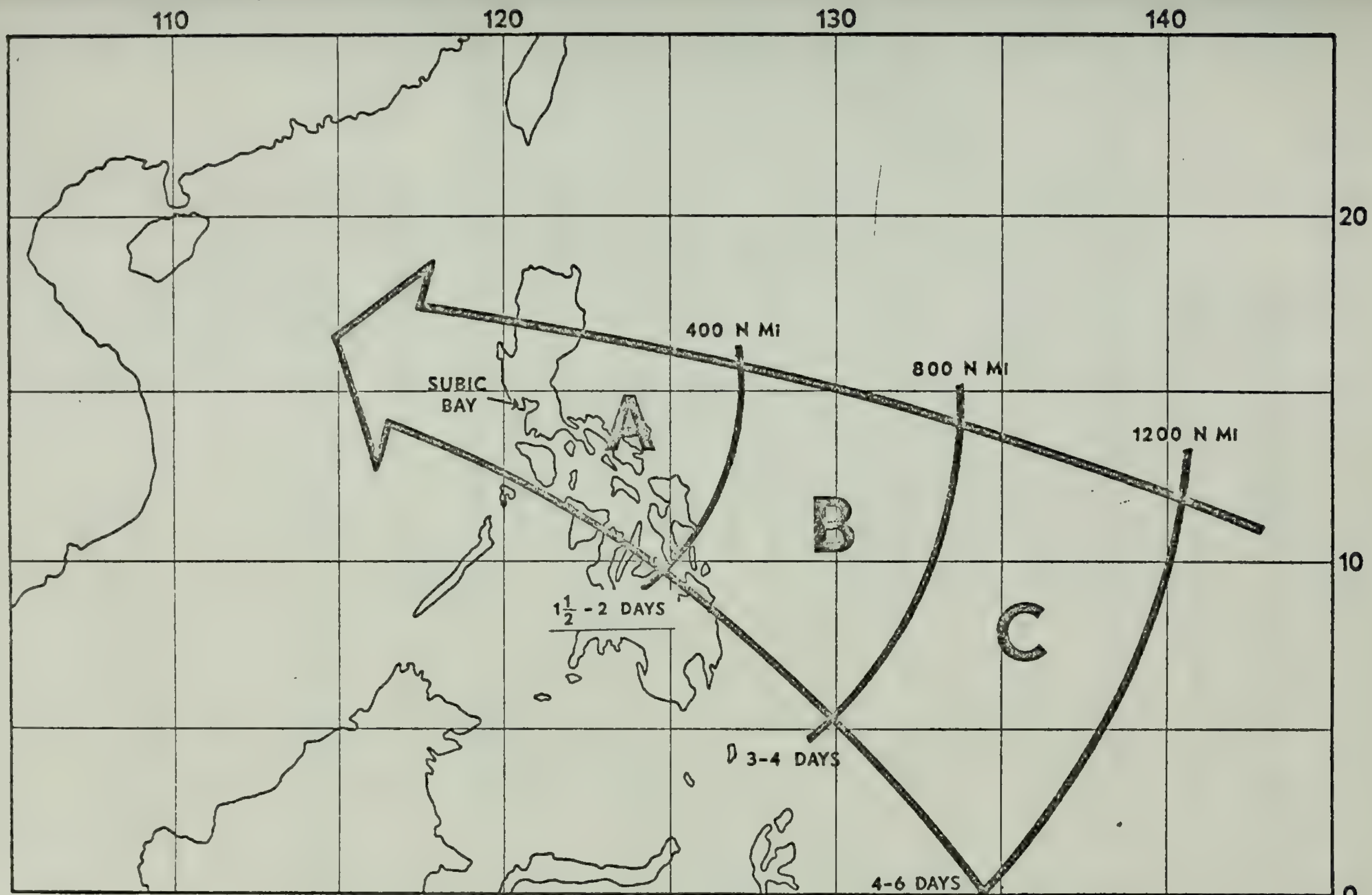

Figure 30. Tropical cyclone threat axis for Subic Bay. Distances and approach times are measured from Subic Bay, based on an 8-12 kt speed of movement.

II. A tropical cyclone entering area B with forecast movement toward Subic Bay.

   a. Operational plans should be made in the event sortie is ordered.

   b. Reconsider all maintenance activities scheduled to exceed 24 hours.

III. A tropical cyclone entering area A with forecast movement toward Subic Bay.

   a. Execute evasion plans made in previous steps.

The final decisions involving evasion of tropical cyclones rests with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion tactics involves running downwind and down sea relative to the typhoon in order to reach a latitude south of the storm and in the navigable semicircle. The success of this method depends upon almost continuous reconnaissance coverage and the relatively slow movement and gradual expansion of the initially small area affected by severe winds that is characteristic of typhoons at low latitudes (Somervell and Jarrell, 1970).

For a ship in or near Subic Bay the following evasion techniques for the more common threat situations are suggested:

1. Tropical cyclone forecast to pass north of Subic Bay:

   a. Evasion should be to the west-southwest since units are already in the navigable semicircle and will remain there.

2. Tropical cyclone forecast to pass east of Subic Bay:

   a. Evasion should be to the west-southwest since an eastward passing tropical cyclone may have already started recurvature and a westward heading will keep the ship in the navigable semicircle.

3. Tropical cyclone forecast to pass south of Subic Bay:

   a. Evasion should be to the west-southwest. This decision should be made as early as possible to preclude a rendezvous with the storm.

It should be noted that some tropical cyclones do generate in the South China Sea each year. However, their normal tracks are to the west and/or north and should not present a threat to units in the Subic Bay area.

In all cases careful monitoring of the storm should be conducted to permit the utilization of the proper evasion technique in the event of a sudden, unpredicted change in storm track.

Whatever evasion decision is made, the following general comments should be considered:

1. When departing Subic Bay, ample time should be given to combat the heavy sea condition likely to be encountered at the entrance to Subic Bay.

2. Crossing ahead of a typhoon should be accomplished well in advance of an approaching typhoon. Heavy swells may be encountered ahead of an advancing typhoon considerably before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing clearance of the typhoon track.[6]

3. At certain times of the year, particularly the peak typhoon season, the possibility exists that two or more tropical storms are present at one time. This would greatly complicate any evasion planning and execution.

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[6]See Appendix E for discussions and examples of the extent to which sea state and wind speed reduce the speed of advance of a vessel.

7. CONCLUSION

Previous texts classifying Subic Bay as a typhoon haven have done so with certain reservations or qualifications. It is true that many ships have successfully weathered the fury of the numerous typhoons that have affected Subic Bay.[7] However, it is also a fact that Subic Bay has never really been tested by the passage of a truly severe tropical cyclone. Those storms whose eyes have crossed directly over Subic Bay have been relatively weak storms; in the case of severe tropical cyclones the eyes have only come close, with the strongest winds missing Subic Bay by 50-100 n mi and the remaining winds being further reduced by the topography of the surrounding terrain.

After considering the above facts and many discussions with experienced personnel at Subic Bay, it is the conclusion of this study that, although Subic Bay does provide some degree of shelter from typhoon passage, it should not be considered an "unqualified" typhoon haven. The sheltering effect provided by the surrounding terrain qualifies Subic Bay as a much safer port in heavy weather than Hong Kong, Kaohsiung, or Chilung (Keelung). However, large combatants (CVA, cruisers, etc.) would find the relatively small size of Subic Bay detrimental and they can generally withstand the rigors of evasion at sea. The cost in terms of time and money would be small since the evasion route would be short and direct. Smaller craft, given ample warning time, should also be able to evade into the navigable semicircle. If ample warning time is not given, or the means to evade does not

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[7]See Appendix F for abstracts of statements from commanding officers of ships located at Subic Bay during the passage of Typhoon "Irma" in May, 1966.

exist, relatively safe typhoon anchorages are present in the inner basin of Port Olongapo for a limited number of small vessels. From Appendix F it is evident that certain anchorages close to the western shore of the bay also provide some degree of shelter.

To aid commanding officers in rapidly evaluating the threat posed to Subic Bay by an individual tropical cyclone, and to aid in decisions thereafter, Figure 31 has been incorporated into this text. Figure 31 is an operationally oriented flow diagram summarizing the locations of the various sections contained in this study.

TROPICAL CYCLONE DEVELOPMENT IN WESTPAC

To determine whether tropical cyclones will or will not affect the area within 400 n mi of Subic Bay, refer to:

a. Section 6.1 (p. 48) which describes tropical cyclone warning information. Examine present warnings.

b. Monthly western North Pacific climatological typhoon tracks in Appendix A (pp. 78-89).

c. Section 5 (pp. 23-47) - tropical cyclone climtology for Subic Bay. In particular Figures 18-24 (pp. 35-41) the percent threat analyses and Figures 25 and 26 (pp. 43-44) the tracks of gale associated storms.

WILL AFFECT SUBIC BAY

TROPICAL CYCLONE WILL AFFECT THE AREA WITHIN 400 N MI OF SUBIC BAY

To determine whether the tropical cyclone will pose a threat (pass within 180 n mi) to Subic Bay refer to:

a. Section 6.1 (p. 48) which describes tropical cyclone warning information available. Examine present warnings being issued.

b. Figures 25 and 26 (pp. 43-44) the tracks of gale associated storms.

c. Sections 5.1 (pp. 23-34) and 5.2 (pp. 34-46) with emphasis on Figure 27 (p. 45) for the position of past storm centers when >22 kt winds began at Subic Bay and Figure 28 (p. 46) for the position of past storm centers when $\geq$34 kt winds began at Subic Bay.

WILL NOT AFFECT SUBIC BAY

TROPICAL CYCLONE WILL NOT AFFECT THE AREA WITHIN 400 N MI OF SUBIC BAY

Continue to monitor storm movement; be alert for significant changes.

NO THREAT TO SUBIC BAY

TROPICAL CYCLONE IS NOT A THREAT TO SUBIC BAY

Continue to monitor storm movement; be alert for significant changes.

THREAT TO SUBIC BAY

TROPICAL CYCLONE WILL POSE A THREAT TO SUBIC BAY

EVASION

With the expectation of a threat to the port, commanders should ensure the readiness of evasion procedures. Refer to:

a. Section 6.1 (p. 48) and 6.3 (pp. 50-53) which cover the major aspects of evasion at sea.

b. Section 5.3 (p.47) for discussion of wave action at Subic Bay, and Appendix E (pp. 97-100) showing the effect on speed of advance of wind and sea conditions.

c. Appendix D (pp. 94-96), "Heavy Weather Plan" for the Philippines.

REMAINING IN PORT

If the ship is to remain in port, refer to:

a. Section 6.2 (pp. 48-50), "Remaining in Port."

b. Section 4.4 (p. 22) and Appendix C (pp. 92-93), "Harbor Facilities."

c. Appendix D (pp. 94-96) "Heavy Weather Plan" for the Philippines.

Figure 31. Flow diagram for Subic Bay.

8. MANILA

8.1 GEOGRAPHICAL LOCATION AND GENERAL DESCRIPTION

Manila is the largest city in the Philippine Islands and is located on the eastern shore of Manila Bay (see Figure 5). Manila Bay is approximately 30 statute miles long, 23 statute miles wide at its widest point, and includes an area of 770 square miles. The entrance to Manila Bay is divided into two channels by Corregidor Island and Caballo Islands. These channels are named North Channel and South Channel, and both are deep and clear of obstructions.

8.2 TOPOGRAPHY

Figure 32 depicts some of the topographical features surrounding Manila and Manila Bay. The Sierra Madre mountains to the east and the mountains on the Bataan Peninsula help to shelter Manila Bay from severe winds.

Figure 33 depicts the bottom topography of Manila Bay. The depths of Manila Bay range from over 180 feet in the entrance to about 90 feet in the center, decreasing gradually to the shore. Note that the bay is very shallow in some places which, along with the relatively poor holding action provided by its sand and soft mud bottom, is why Manila Bay is <u>not</u> considered a haven during typhoon passage.

8.3 MANILA HARBOR

The port of Manila consists of the North and South Harbors, both of which are protected by breakwaters. Figure 34 is a diagram of Manila Harbor. The Pasig River separates the two harbors and is navigable to a distance of one mile from its mouth by small vessels drawing up to 10 feet. The North Harbor is the smaller of the two harbors and is used

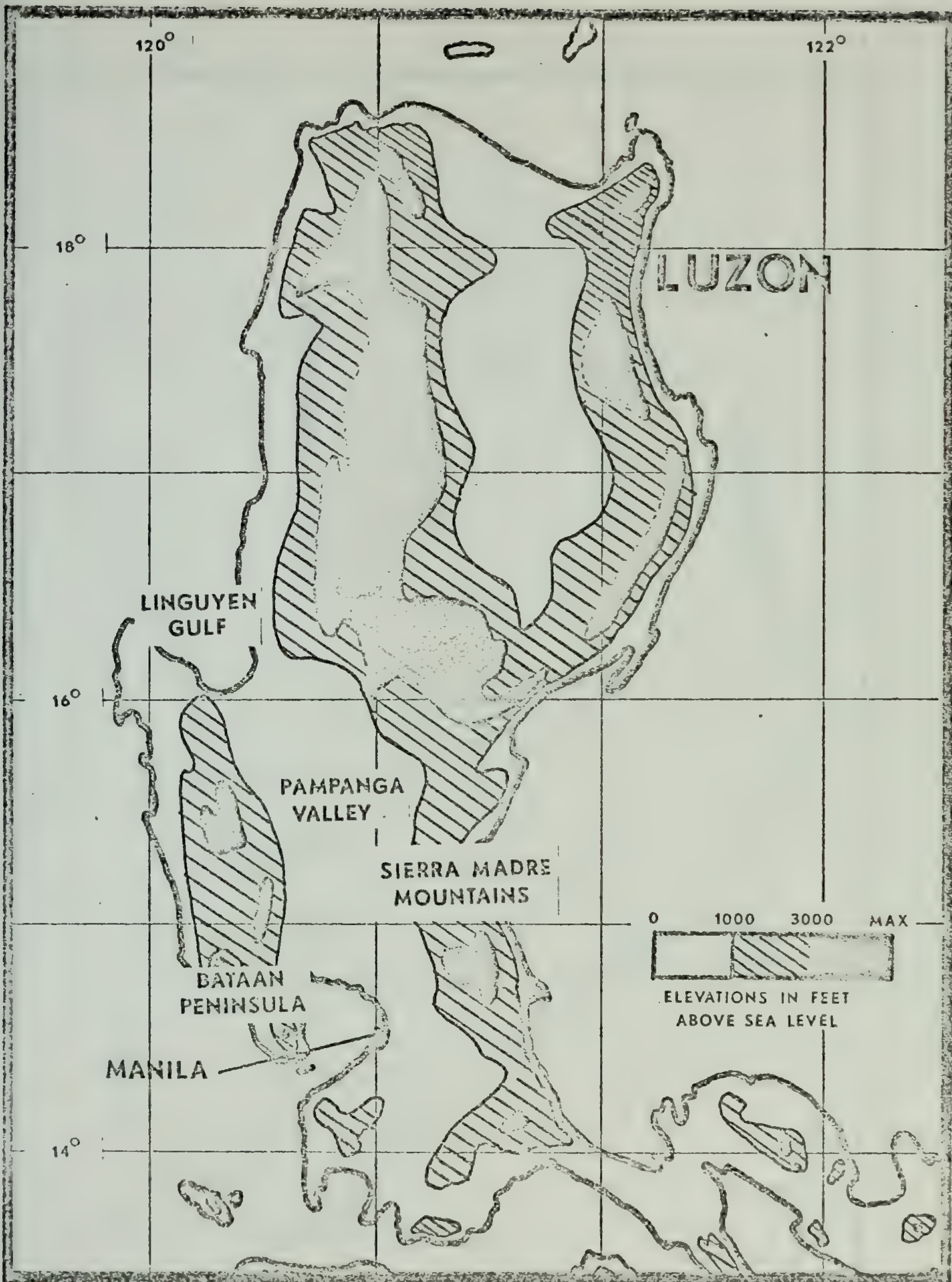

Figure 32. Topographical map of Luzon showing approximate elevation above sea level and the location of Manila.

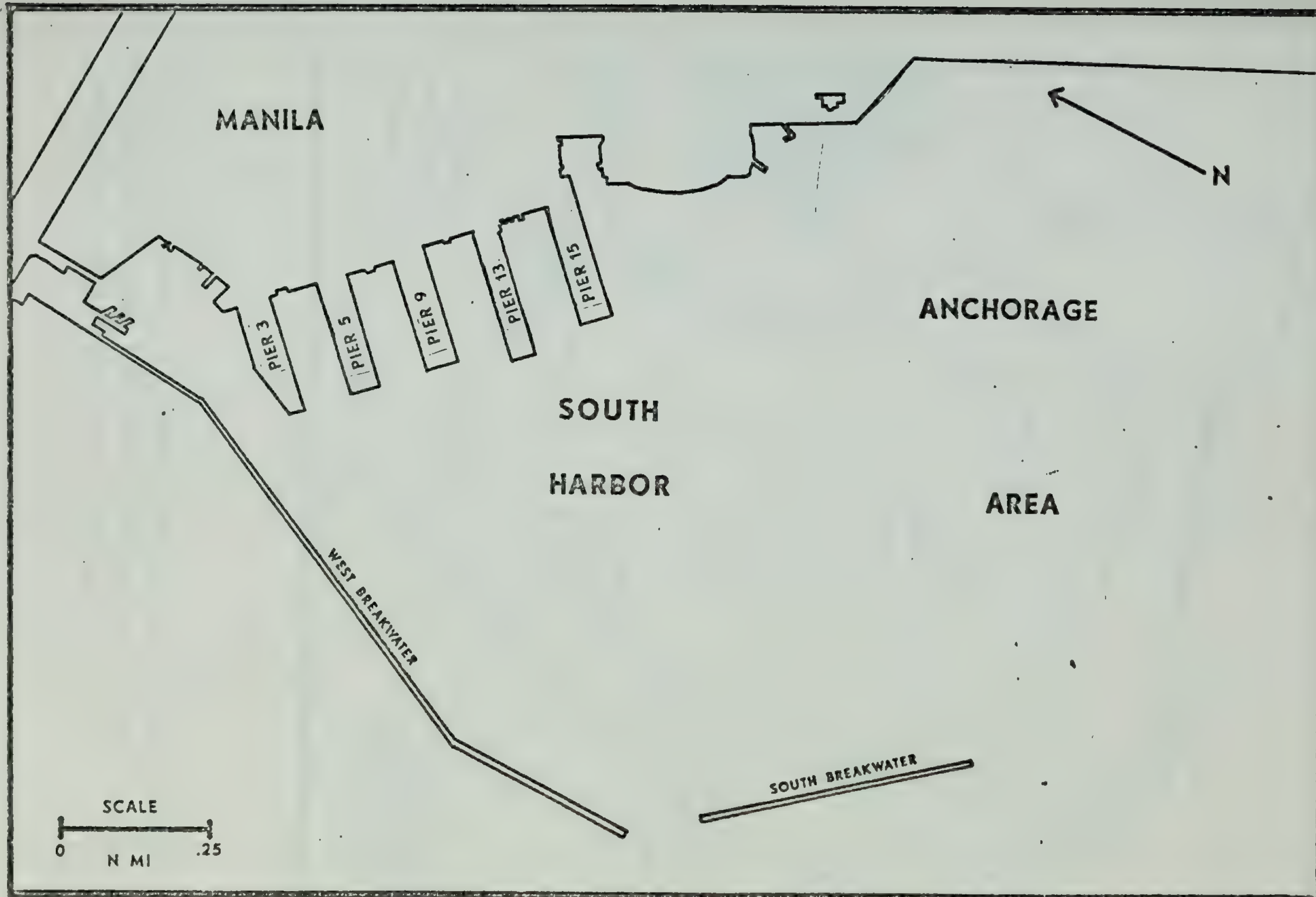

Figure 33. Depth contours (in ft) in Manila Bay.

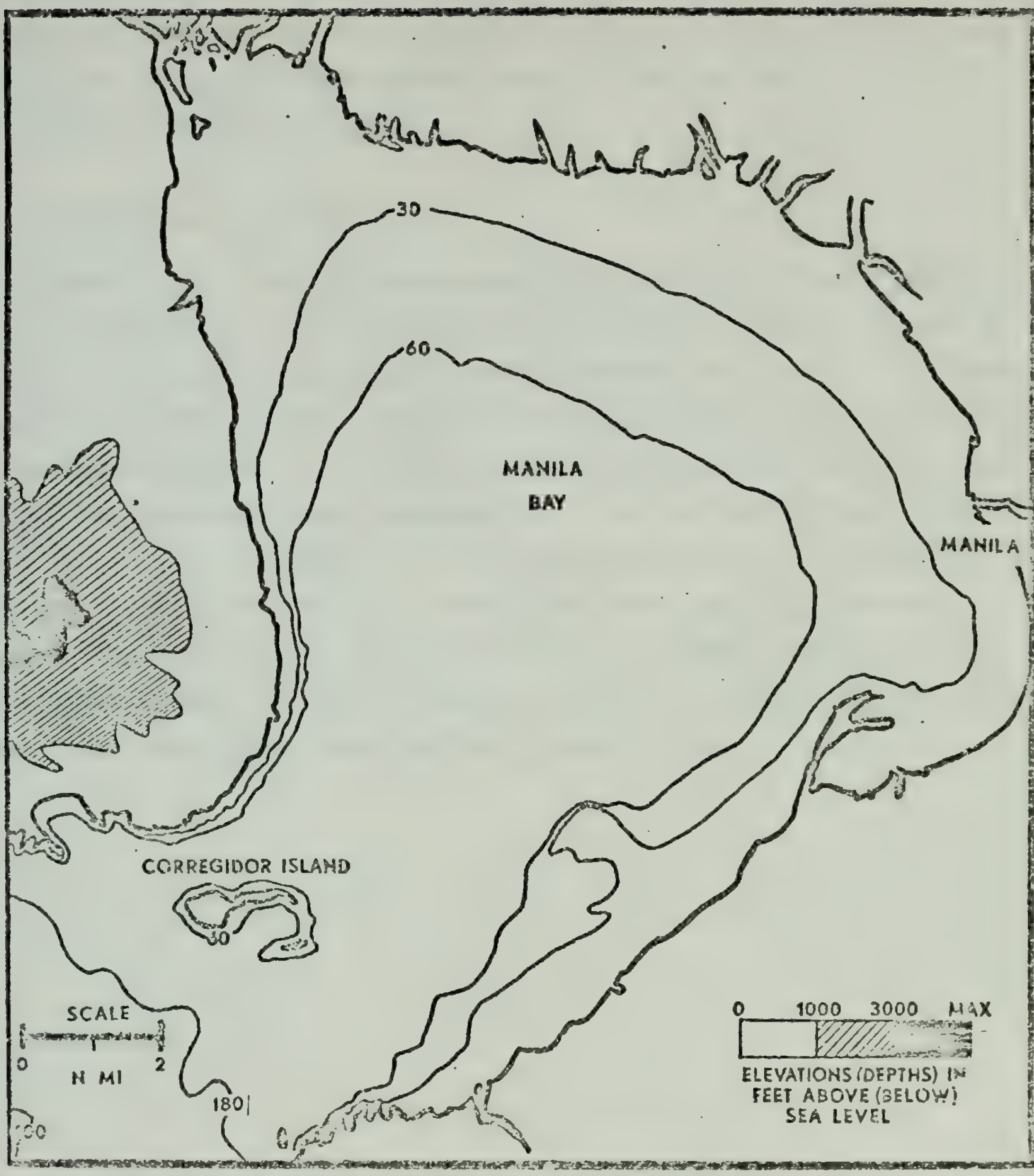

Figure 34. Manila Harbor plan showing the location of piers and anchorage areas which can be assigned to U.S. Navy and contracted DOD vessels.

solely for inter-island shipping. The South Harbor is used for large ocean-going vessels and is the harbor that will be considered in this study.

8.4 HARBOR FACILITIES

There are five odd-numbered piers that extend southeastward from the northern side of South Harbor. These piers contain the principal deep-draft berths and range in depth from 9 to 36 ft. Pier characteristics are not standardized and are contained in Appendix B. There are anchorages, both inside and outside the breakwater, for an unlimited number of vessels of all classes. The anchorages range in depth from 8 to 22 fathoms with less than adequate holding ground. It should be noted that with the return of NAS Sangley Point to Philippine control, U. S. Navy and DOD contract vessels no longer are assigned special anchorage areas.

9. TROPICAL CYCLONES AFFECTING MANILA

9.1 CLIMATOLOGY

Refer to section 5.1 for the tropical cyclone climatology of Manila.

9.2 WIND AND TOPOGRAPHICAL EFFECTS

In the 19-yr period from 1955-1973, for the months June-December a total of 83 tropical cyclones approached within 180 n mi of Manila.[8] This is an average of more than four tropical cyclones per year. The largest number of tropical cyclones approaching Manila in any single year was eleven in 1964. Table 2 groups the above 83 tropical cyclones according to the wind intensity that they produced at Manila.[9] Of the 83 tropical cyclones concerned, 28.5% resulted in strong winds ($\geq$22 kt) at Manila and only 8.4% resulted in gale force winds there ($\geq$34 kt).

Table 2. Extent to which tropical cyclones affected Manila during the period June-December, 1955-1973.

Number of tropical cyclones that passed within 180 n mi of Manila	83
Number of tropical cyclones resulting in strong winds ($\geq$22 kt) at Manila	24
Number of tropical cyclones resulting in gale force winds ($\geq$34 kt) at Manila	7

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[8] From Chin (1972) for years 1955-1970 and from Annual Typhoon Reports for 1971-1973 (U.S. FWC/JTWC, 1971-1973).

[9] The wind data for Manila is from NAS Sangley Point for the years 1955-1968. For the remaining years, 1969-1973, the data were taken from a wind gage at the mouth of the Pasig River and are verified to be representative of the wind in Manila Bay.

It is apparent from Table 2 that Manila must be an extremely sheltered harbor. Figure 32 depicts the sheltering effect of the terrain surrounding Manila. The Sierra Madre mountains to the east and the Bataan Peninsula to the west effectively serve as a wind barrier for Manila. When gale force winds do appear they are generally funneled from the Linguyen Gulf through the Pampanga Valley to Manila.

Figure 35 depicts the tracks of tropical cyclones occurring during the period 1955-1973 that resulted in gale force winds at Manila. From their orientation and a comparison with the percent threat figures in section 5.1 it is evident that tropical cyclones approaching from the east and east-southeast represent the primary threat to Manila.

Figure 36 shows the position of tropical cyclone centers when the wind first and last exceeded 22 kt at Manila. Figure 37 shows the positions of tropical cyclone centers when the wind first and last exceeded 34 kt at Manila. Notice that the relatively few tropical cyclones resulting in gale force winds began affecting Manila very close to, or after, tropical cyclone passage. Those tropical cyclones resulting in strong winds did not affect Manila until the cyclone centers were very close to the east coast of the Philippines, but tropical cyclones several hundred miles to the west of the Philippines still had an effect on the winds experienced at Manila.

9.3 WAVE ACTION

Quantitative information on wave height data for Manila Harbor or Manila Bay is not readily available. However, when a typhoon is over or near the Linguyen Gulf and funneling winds through the Pampanga Valley to Manila, the strongest winds are experienced in the bay. These strong winds present more of a hazard to ships in the bay than do the waves they generate.

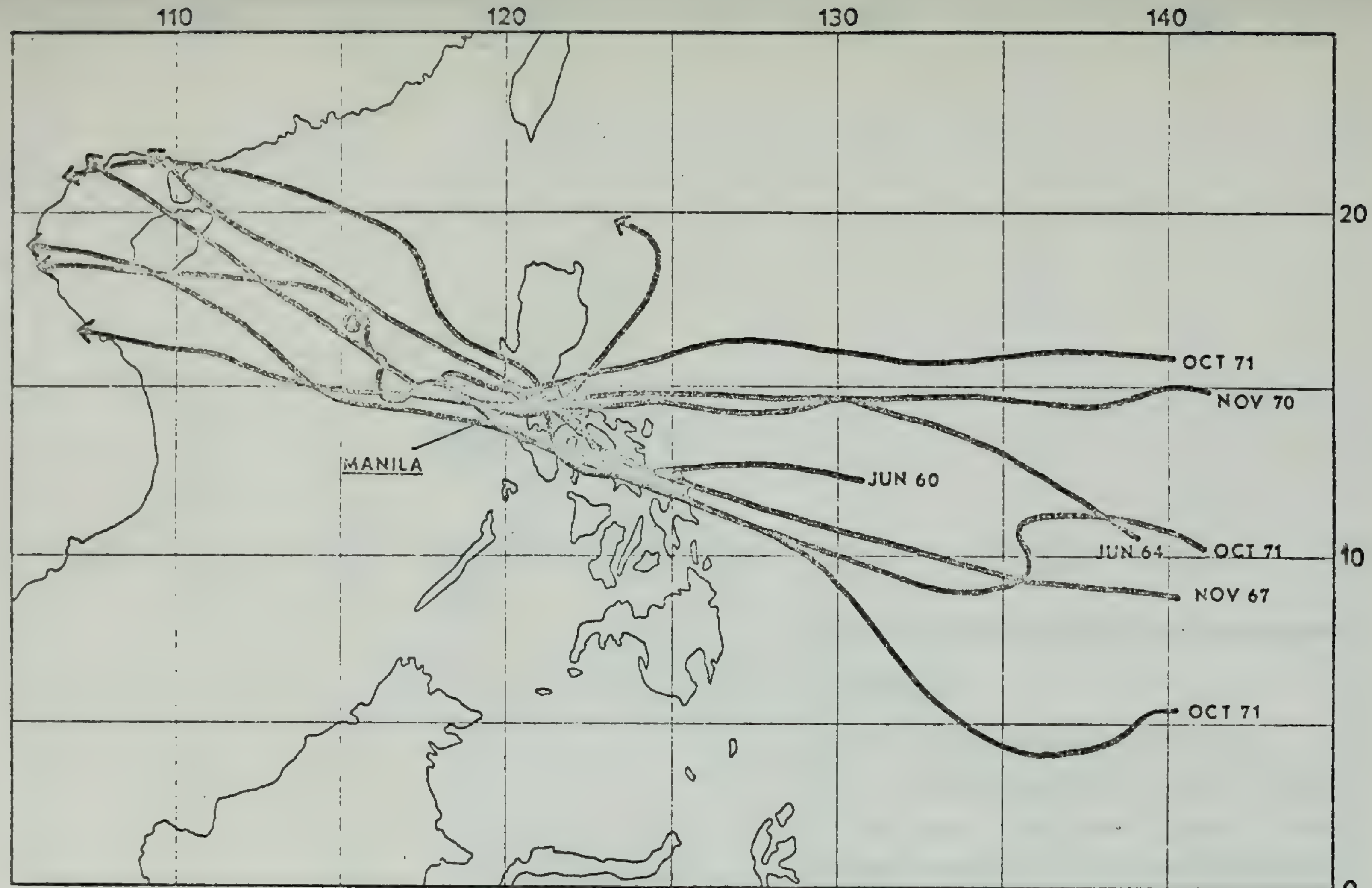

Figure 35. Tracks of tropical cyclones associated with gale force (or greater) winds at Manila. (Based on data from 1955-1973.)

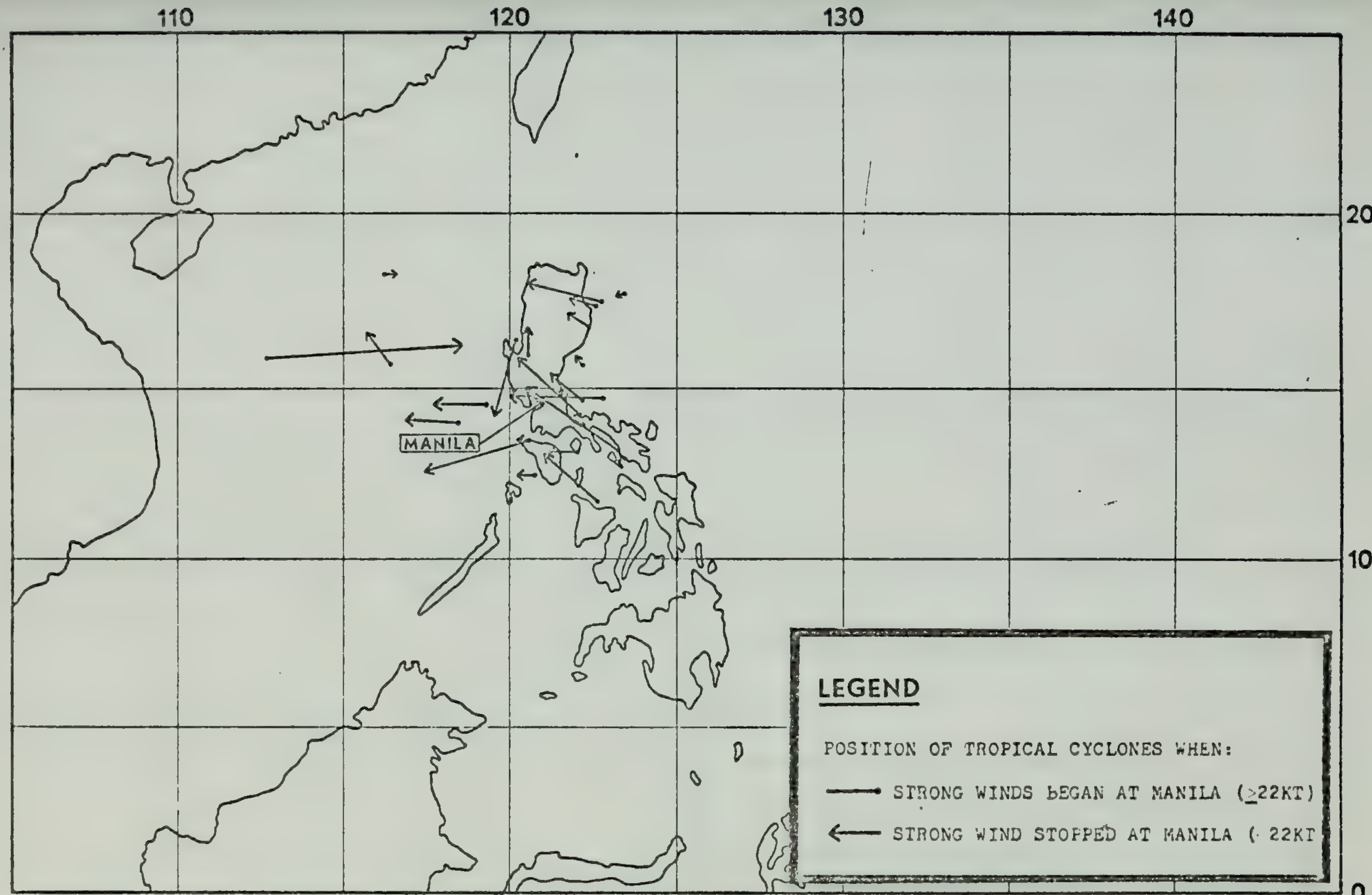

Figure 36. Position of tropical cyclone centers when >22 kt winds first and last occurred at Manila. (Based on data from 1955-1973.)

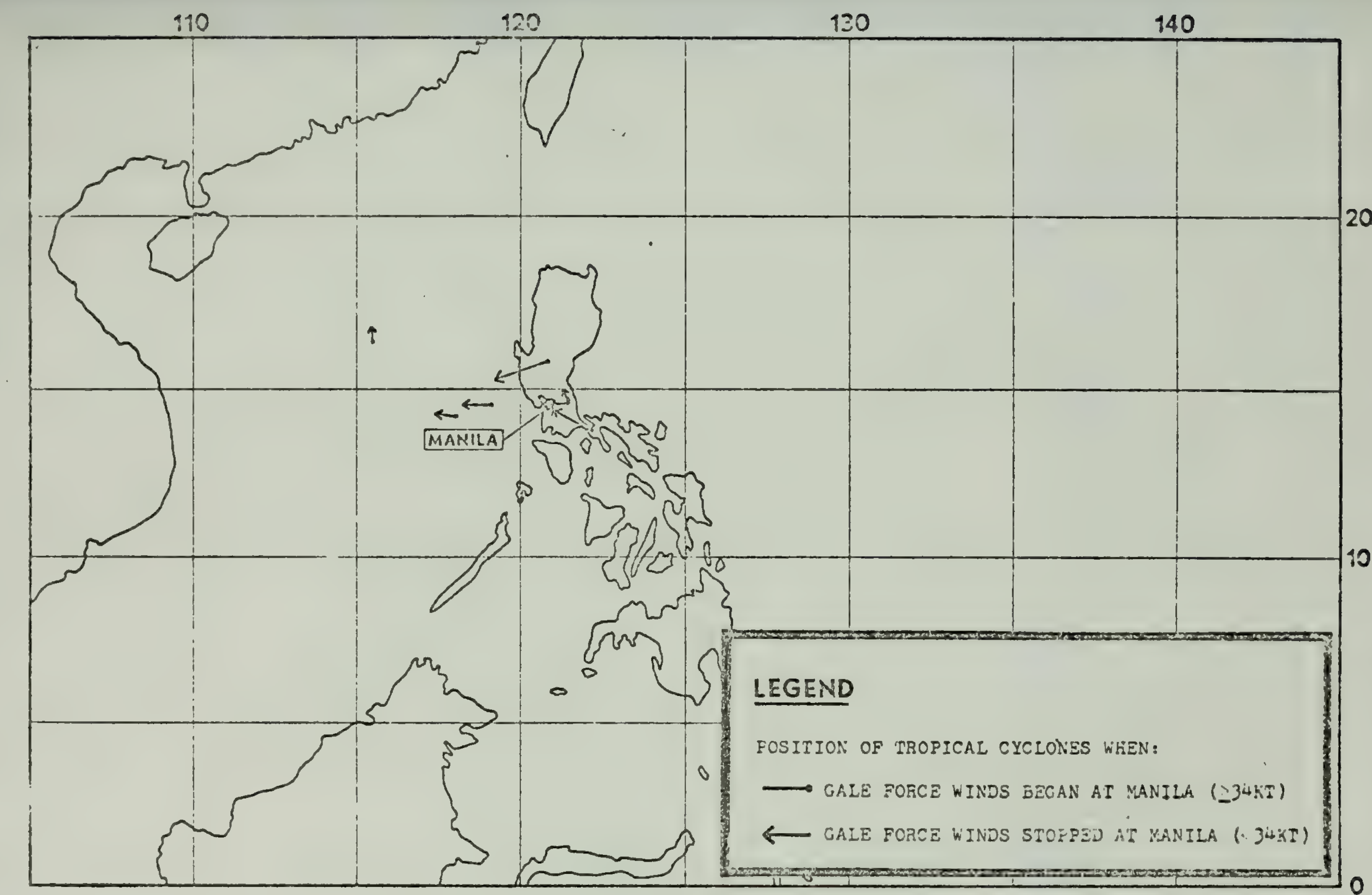

Figure 37. Position of tropical cyclone centers when >34 kt winds first and last occurred at Manila. (Based on data from 1955-1973.)

Due to the relatively short fetch and shallow bottom, the generated waves could reach ten feet or more in significant height but should not build to excessively high levels.

The swell coming into the bay is damped considerably by Corregidor Island which sets in the mouth of the bay. It serves to split the swell and reflect it to either side. The possibility of shoaling, the building in magnitude of waves when the water depth reaches one-half their wavelength, occurs when the reflected swell reaches the shallower portions of the bay.[10]

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[10]See Hydrographic Office Pub. No. 604 for a detailed discussion on shoaling.

10. PREPARATION FOR HEAVY WEATHER

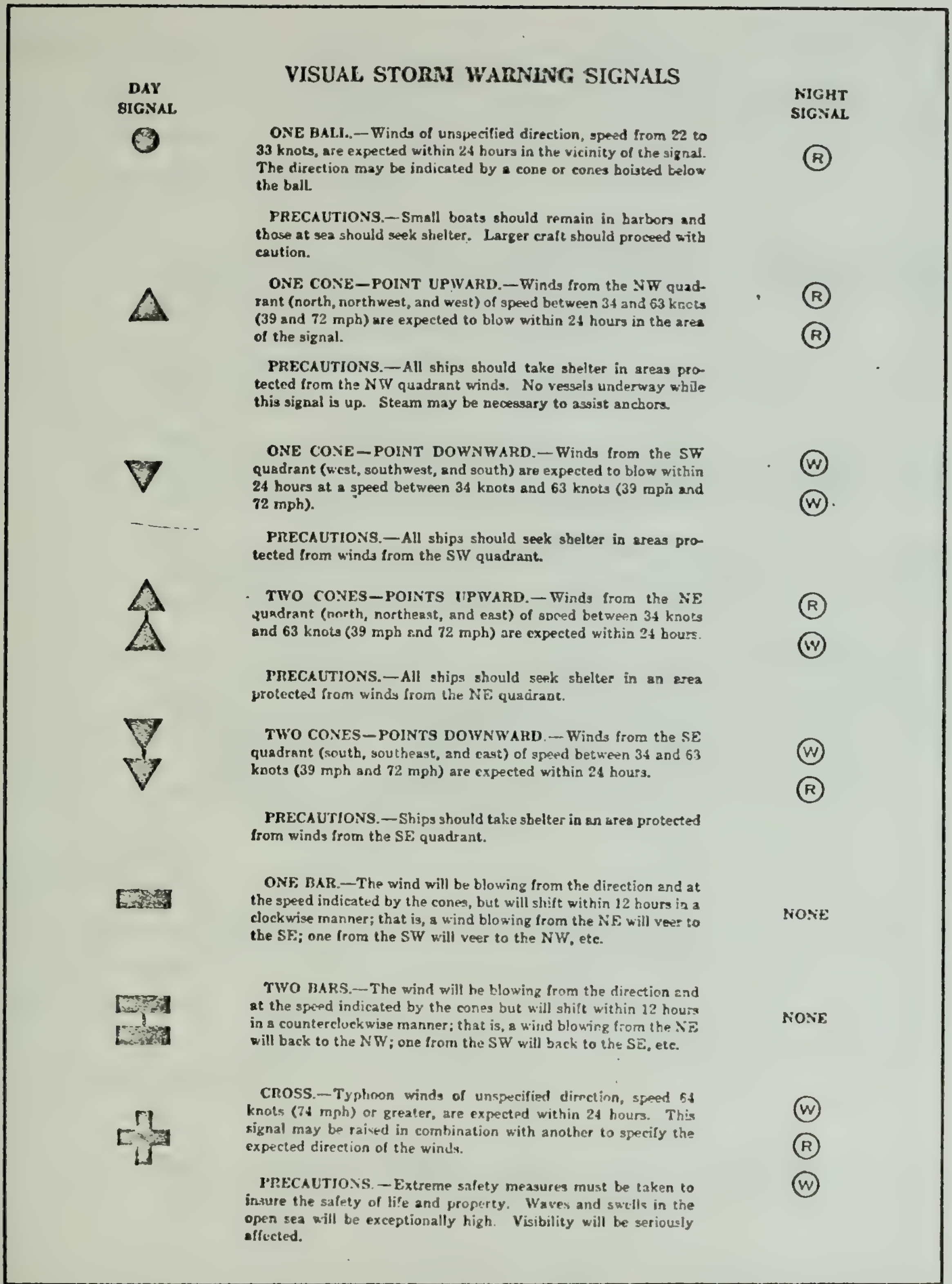
10.1 TROPICAL CYCLONE WARNINGS

Tropical cyclone warnings including 24-, 48-, and 72-hr forecasts are supplied by the Fleet Weather Central/Joint Typhoon Warning Center (FWC/JTWC) located on Guam. COMSEVENTHFLT OPORD 201-(YR), Annex W, describes the procedures and techniques to be used when plotting the FWC/JTWC typhoon warning track positions. Figure 29 demonstrates these procedures, utilizing the 135 n mi average 24-hr forecast position error in obtaining the "danger area." This is necessary in order to expand the radius of 30-kt winds, given in the warning by the average forecast error. Note the radius of 30-kt winds is usually greater on the right side of the storm track -- the dangerous semicircle. In this example, the radius to the 30-kt isotach is 200 n mi to the north and 150 n mi to the south. The 24-hr forecast predicts the radius to expand to 225 n mi to the north and 175 n mi to the south. Adding the average 24-hr forecast position error to the above figures forecasts a 24-hr danger area extending 360 n mi to the north and 310 n mi to the south. The 48- and 72-hr forecast positions given in the FWC/JTWC warning provide for a 275 n mi and 400 n mi average forecast error, respectively.

Section 6 of Appendix I to Annex W to COMNAVPHIL OPORD 201-72 discusses the criteria for setting local heavy weather readiness conditions and is reprinted as Appendix D in this study. Figure 38 presents the visual storm warning signals used in Manila harbor.

10.2 REMAINING IN PORT

Remaining in port when the means to evade a storm is available is a decision that is contrary to most of the traditional rules of seamanship. However, if the decision to



VISUAL STORM WARNING SIGNALS

DAY SIGNAL		NIGHT SIGNAL
	ONE BALL.—Winds of unspecified direction, speed from 22 to 33 knots, are expected within 24 hours in the vicinity of the signal. The direction may be indicated by a cone or cones hoisted below the ball. **PRECAUTIONS.**—Small boats should remain in harbors and those at sea should seek shelter. Larger craft should proceed with caution.	R
	ONE CONE—POINT UPWARD.—Winds from the NW quadrant (north, northwest, and west) of speed between 34 and 63 knots (39 and 72 mph) are expected to blow within 24 hours in the area of the signal. **PRECAUTIONS.**—All ships should take shelter in areas protected from the NW quadrant winds. No vessels underway while this signal is up. Steam may be necessary to assist anchors.	R R
	ONE CONE—POINT DOWNWARD.—Winds from the SW quadrant (west, southwest, and south) are expected to blow within 24 hours at a speed between 34 knots and 63 knots (39 mph and 72 mph). **PRECAUTIONS.**—All ships should seek shelter in areas protected from winds from the SW quadrant.	W W
	TWO CONES—POINTS UPWARD.—Winds from the NE quadrant (north, northeast, and east) of speed between 34 knots and 63 knots (39 mph and 72 mph) are expected within 24 hours. **PRECAUTIONS.**—All ships should seek shelter in an area protected from winds from the NE quadrant.	R W
	TWO CONES—POINTS DOWNWARD.—Winds from the SE quadrant (south, southeast, and east) of speed between 34 and 63 knots (39 mph and 72 mph) are expected within 24 hours. **PRECAUTIONS.**—Ships should take shelter in an area protected from winds from the SE quadrant.	W R
	ONE BAR.—The wind will be blowing from the direction and at the speed indicated by the cones, but will shift within 12 hours in a clockwise manner; that is, a wind blowing from the NE will veer to the SE; one from the SW will veer to the NW, etc.	NONE
	TWO BARS.—The wind will be blowing from the direction and at the speed indicated by the cones but will shift within 12 hours in a counterclockwise manner; that is, a wind blowing from the NE will back to the NW; one from the SW will back to the SE, etc.	NONE
	CROSS.—Typhoon winds of unspecified direction, speed 64 knots (74 mph) or greater, are expected within 24 hours. This signal may be raised in combination with another to specify the expected direction of the winds. **PRECAUTIONS.**—Extreme safety measures must be taken to insure the safety of life and property. Waves and swells in the open sea will be exceptionally high. Visibility will be seriously affected.	W R W

Figure 38. Visual storm warning signals which are utilized at South Harbor in Manila (H.O. Pub. No. 90, 1969).

remain in port is made, it should not be done without every available fact concerning the impending storm and the port in which the vessel is berthed. In the case of Manila harbor the following should be noted:

1. Securing to a pier or anchoring in Manila Bay should be done prior to the onset of 20-kt winds to prevent undue difficulty in mooring.

2. No berths in Manila harbor can be considered sheltered.

3. Manila Bay is extremely shallow in places and contains relatively poor holding ground since the bottom consists of soft mud and sand.

4. Marveles harbor is the most secure harbor in times of weather stress, but it is only large enough to accommodate two or three ships safely.

5. South harbor in Manila harbor is a crowded harbor and at any given time can contain many merchant ships. Some of these vessels may be equipped with inadequate or poorly maintained mooring gear. As a result, it is not uncommon for them to break loose and cause damage to other ships in port.

10.3 EVASION

When evasion of a tropical cyclone is being considered, the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. The following timetable depicted in Figure 39, has been constructed for this purpose:

1. An existing tropical cyclone, or potential development, in area C with forecast movement toward Manila:

    a. Review the material condition of the ship; sailing within 2-4 days is a distinct possibility.

    b. Reconsider all maintenance activities scheduled to exceed 48 hours.

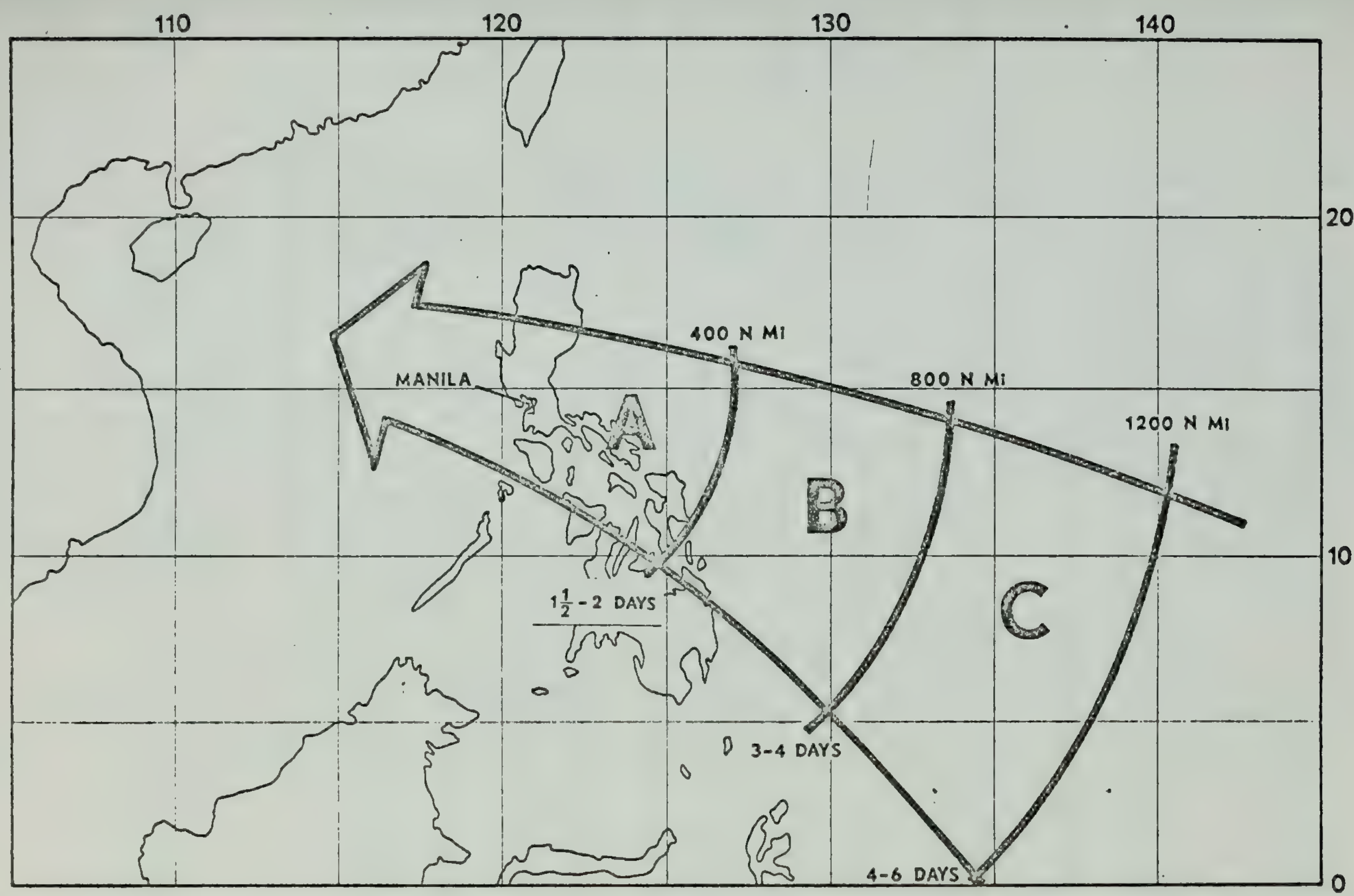


Figure 39. Tropical cyclone threat axis for Manila. Distances and approach times are measured from Manila, based on an 8-12 kt speed of movement.

2. A tropical cyclone entering area B with forecast movement toward Manila:

   a. Operational plans should be made in the event sortie is ordered.

   b. Reconsider all maintenance activities scheduled to exceed 24 hours.

3. A tropical cyclone entering area A with forecast movement toward Subic Bay:

   a. Execute evasion plans made in previous steps.

The final decision involving evasion of tropical cyclones rests with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion tactics involves running downwind and down sea relative to the tropical cyclone in order to reach a latitude south of the storm and in the navigable semicircle. The success of this method is due to almost continuous reconnaissance coverage and the relatively slow movement and gradual expansion of the initially small area affected by severe winds that is characteristic of typhoons at low latitudes.

For a ship in or near Manila, the following evasion techniques for the more common threat situations are suggested:

1. Tropical cyclone forecast to pass north of Manila:

   a. Evasion should be to the west-southwest since units are already in the navigable semicircle and will remain there.

2. Tropical cyclone forecast to pass east of Manila:

   a. Evasion should be to the west-southwest since an eastward passing tropical cyclone may have already started recurvature and a westward heading will keep the ship in the navigable semicircle.

3. Tropical cyclone forecast to pass south of Manila:

   a. Evasion should be to the west-southwest. This decision should be made as early as possible to preclude a rendezvous with the storm.

It should be noted that some tropical cyclones do generate in the South China Sea each year. However, their normal tracks are to the west and/or north and should not present a threat to units in the Manila area.

In all cases careful monitoring of the storm should be conducted to permit the proper evasion technique to be employed in the event of a sudden, unpredicted change in track by the storm.

Whatever evasion decision is made the following general comments should be considered.

1. Even weak typhoons crossing the Philippine Islands can quickly result in strong winds in Manila Bay. The decision to sortie should be made far enough in advance to preclude difficulties in exiting Manila Bay.

2. Crossing ahead of a typhoon should be accomplished well in advance of the approaching typhoon. Heavy swells may be encountered ahead of the advancing typhoon considerably before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing clearance of the typhoon track.[11]

3. At certain times of the year, particularly the peak typhoon season, the possibility exists that two or more tropical storms are present. This would greatly complicate any evasion planning and execution.

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[11] See Appendix E for discussion and examples of the extent to which sea state and wind speed reduce speed of advance.

11. CONCLUSION

It is the conclusion of this study that Manila harbor is not a safe harbor and Manila Bay is not a safe refuge during a passage of a typhoon. The policy of the Port Captain of the South Harbor, Manila, is to evacuate all vessels at least 24 hours prior to typhoon passage. The harbor is extremely busy and congested with primarily merchant and commercial shipping vessels. These vessels are, more often than not, equipped with inadequate or inferior mooring equipment and they may evacuate to any area in Manila Bay outside the confines of South Harbor. Because of the danger of ships breaking loose from anchor during the storm and the shallowness of the bay, it is recommended that all U. S. Navy or contracted DOD vessels sortie from Manila Bay as well as from Manila harbor. Since the evasion route is generally southwesterly into the South China Sea, the sortie should be relatively short, low in operating costs, and free of peril.

To aid commanding officers in rapidly evaluating the threat posed to Manila by an individual tropical cyclone, and to aid in decisions thereafter, Figure 40 has been incorporated into this text. Figure 40 is an operationally oriented flow diagram summarizing the locations of the various sections contained in this study.

TROPICAL CYCLONE DEVELOPMENT IN WESTPAC

To determine whether tropical cyclones will or will not affect the area within 400 n mi of Manila, refer to:

a. Section 10.1 (p. 68) which describes tropical cyclone warning information. Examine present warnings.

b. Monthly western North Pacific climatological typhoon tracks in Appendix A (pp. 78-89).

c. Section 5.1 (pp. 23-34) - tropical cyclone climatology for Manila. In particular, Figures 18-24 (pp. 35-41), the percent threat analyses, and Figure 35 (p. 64), the tracks of gale associated storms.

WILL AFFECT MANILA

TROPICAL CYCLONE WILL AFFECT THE AREA WITHIN 400 N MI OF MANILA

To determine whether the tropical cyclone will pose a threat (pass within 180 n mi) to Manila, refer to:

a. Section 10.1 (p. 68) which describes tropical cyclone warning information available. Examine present warnings being issued.

b. Figure 35 (p. 64), the tracks of gale associated storms.

c. Sections 5.1 (pp. 23-34) and 9.2 (pp. 62-63) with emphasis on Figure 36 (p. 65) for the position of past storm centers when >22 kt winds began at Manila and Figure 37 (p. 66) for the position of past storm centers when ≥34 kt winds began at Manila.

WILL NOT AFFECT MANILA

TROPICAL CYCLONE WILL NOT AFFECT THE AREA WITHIN 400 N MI OF MANILA

Continue to monitor storm movement; be alert for significant changes.

NO THREAT TO MANILA

TROPICAL CYCLONE IS NOT THREAT TO MANILA

Continue to monitor storm movement; be alert for significant changes.

THREAT TO MANILA

TROPICAL CYCLONE WILL POSE A THREAT TO MANILA

EVASION

With the expectation of a threat to the port, commanders should ensure the readiness of evasion procedures. Refer to:

a. Sections 10.1 (p. 68) and 10.3 (pp. 70-73) which cover the major aspects of evasion at sea.

b. Section 9.3 (pp. 63-64) for discussion of wave action at Manila, and Appendix E (pp. 97-100) showing the effect on speed of advance of wind and sea conditions.

c. Appendix D (pp. 94-96), "Heavy Weather Plan" for the Philippines.

REMAINING IN PORT

If the ship is to remain in port, refer to:

a. Section 10.2 (pp. 68-70), "Remaining in Port."

b. Section 8.4 (p. 61) and Appendix B (pp. 90-91), "Harbor Facilities."

c. Appendix D (pp. 94-96), "Heavy Weather Plan" for the Philippines and Figure 38 (p. 69), visual storm signals used at Manila.

Figure 40. Flow diagram for Manila.

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APPENDIX A

Figures A-1 through A-11 show monthly and half monthly (June to December) tracks of western North Pacific tropical cyclones (1946-1969) which were at one time of typoon intensity. The tropical cyclones have been placed into monthly categories according to the median date of their existence (from Gray, 1970).

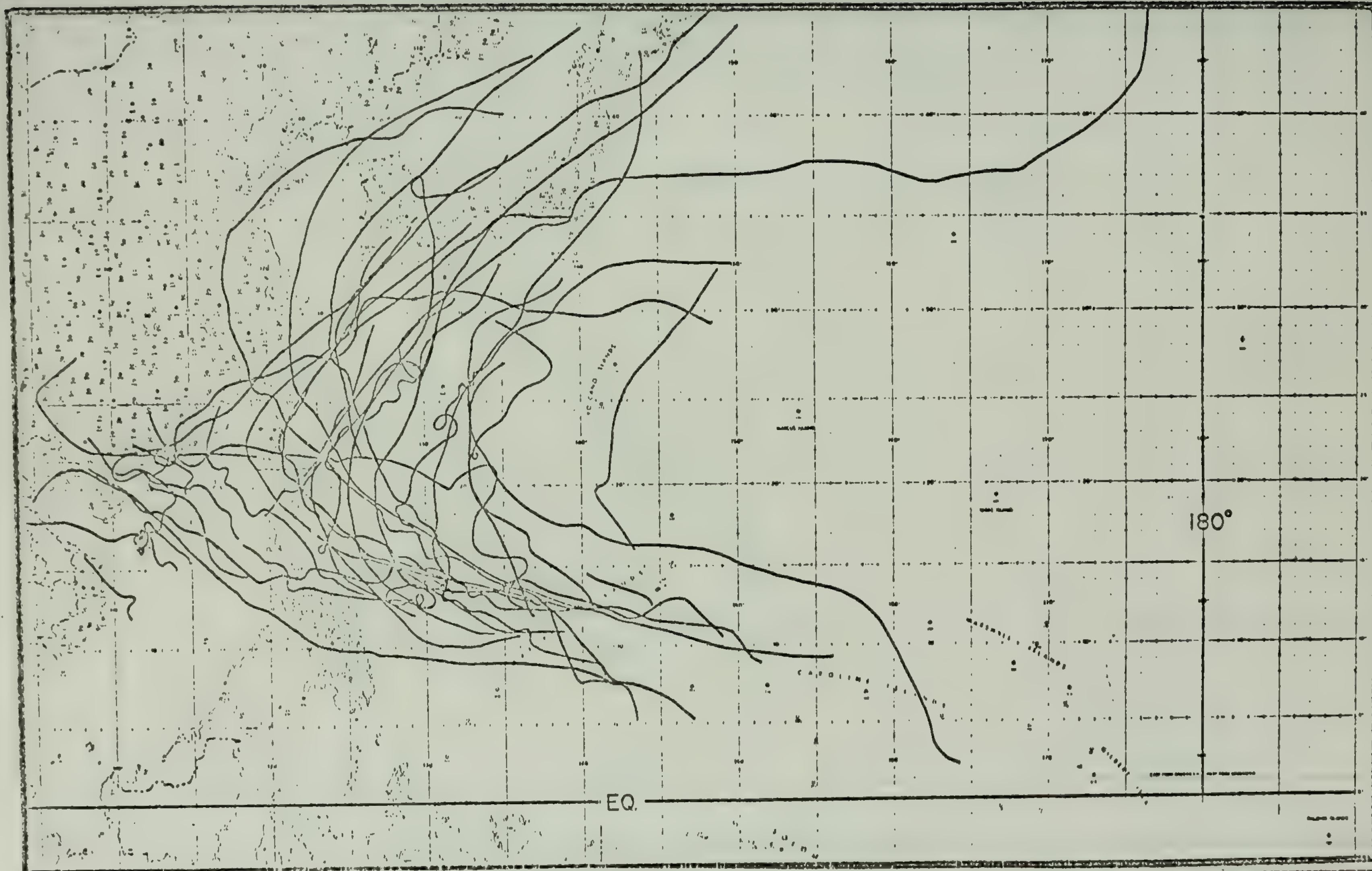

Figure A-1. Tracks of tropical cyclones which at some time were typhoons during the month of June for the years 1946-1969.

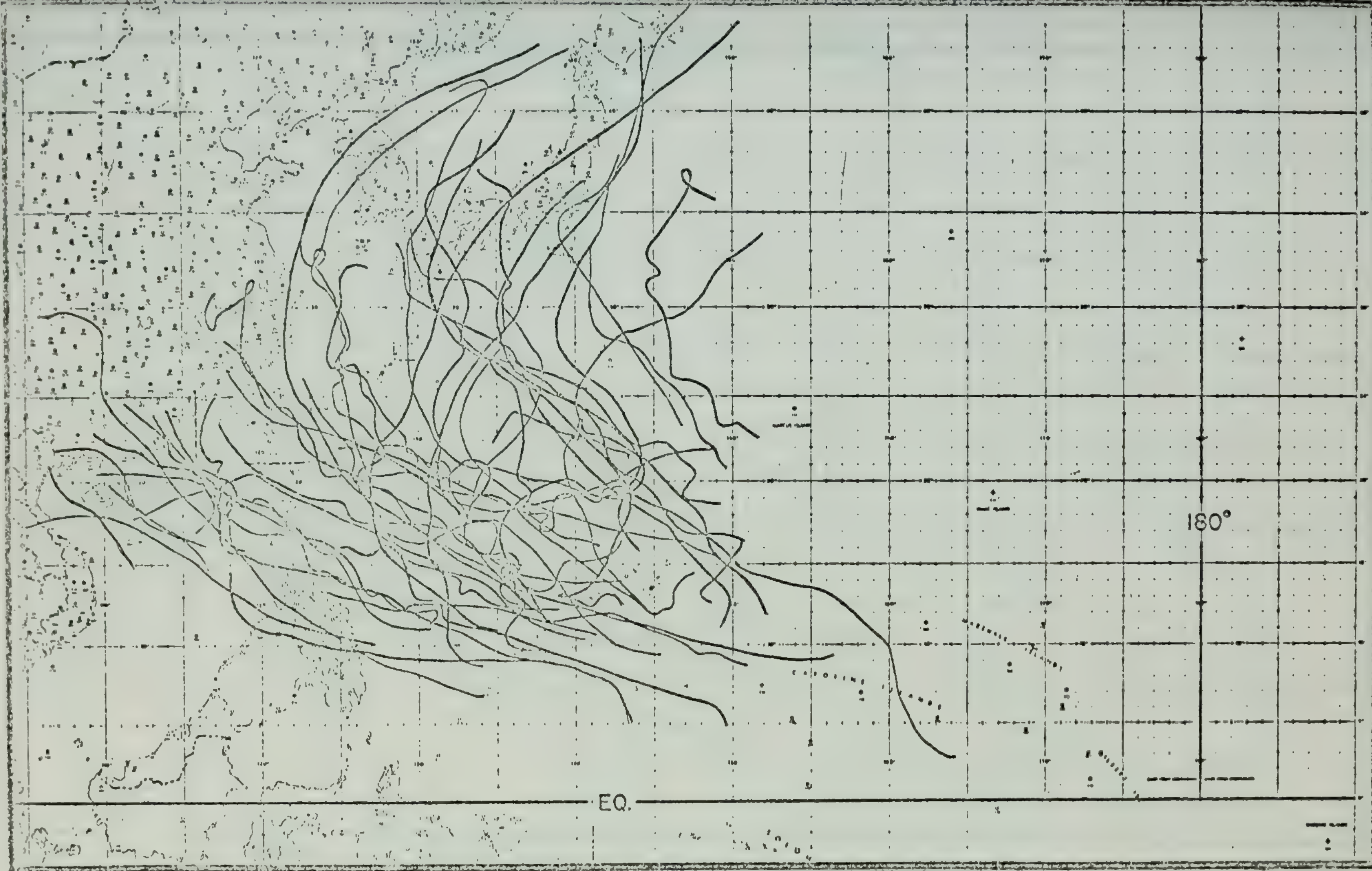

Figure A-2. Tracks of tropical cyclones which at some time were typhoons during the month of July (first half) for the years 1946-1969.

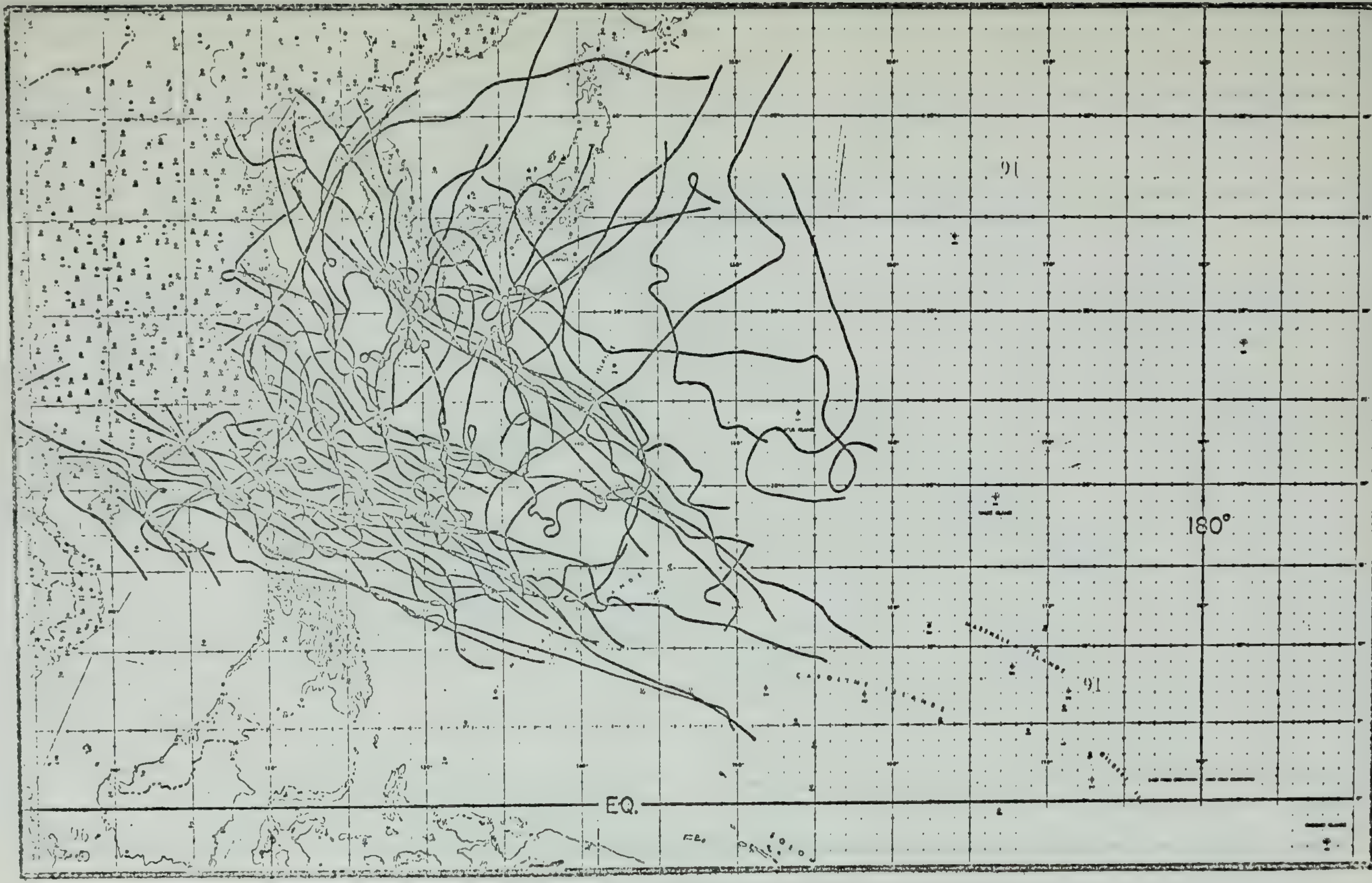

Figure A-3. Tracks of tropical cyclones which at some time were typhoons during the month of July (second half) for the years 1946-1969.

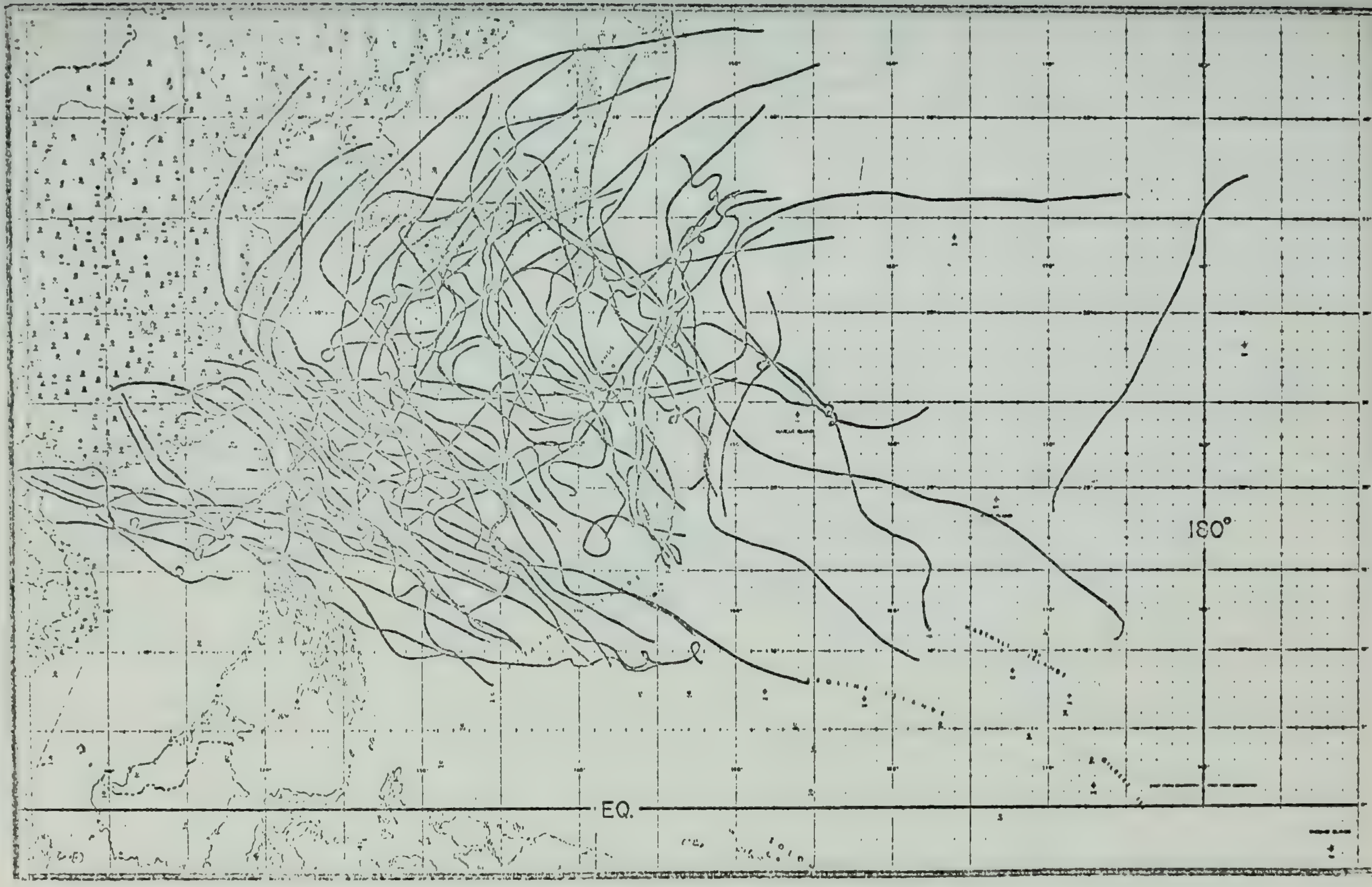

Figure A-4. Tracks of tropical cyclones which at some time were typhoons during the month of August (first half) for the years 1946-1969.

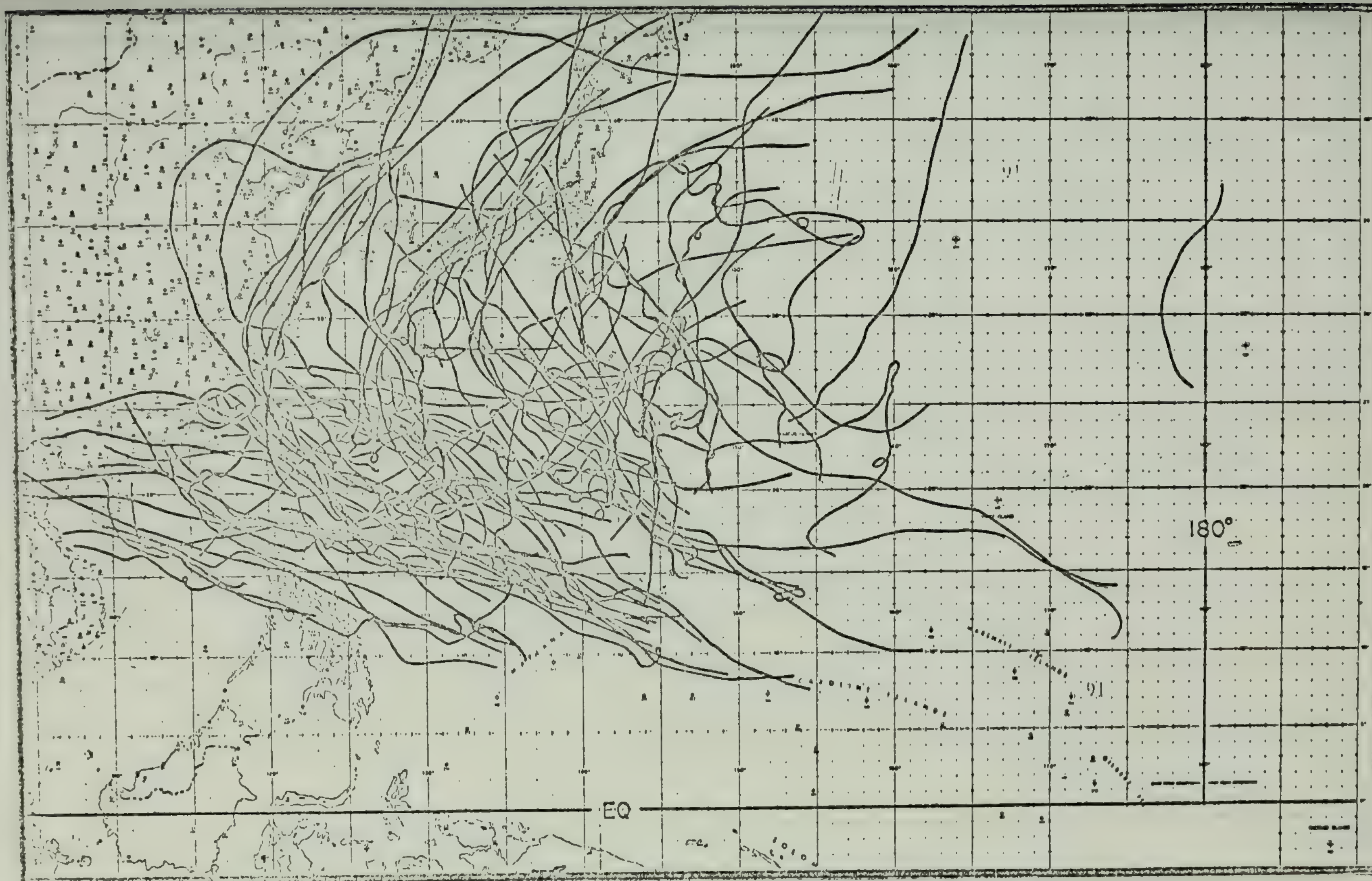

Figure A-5. Tracks of tropical cyclones which at some time were typhoons during the month of August (second half) for the years 1946-1969.

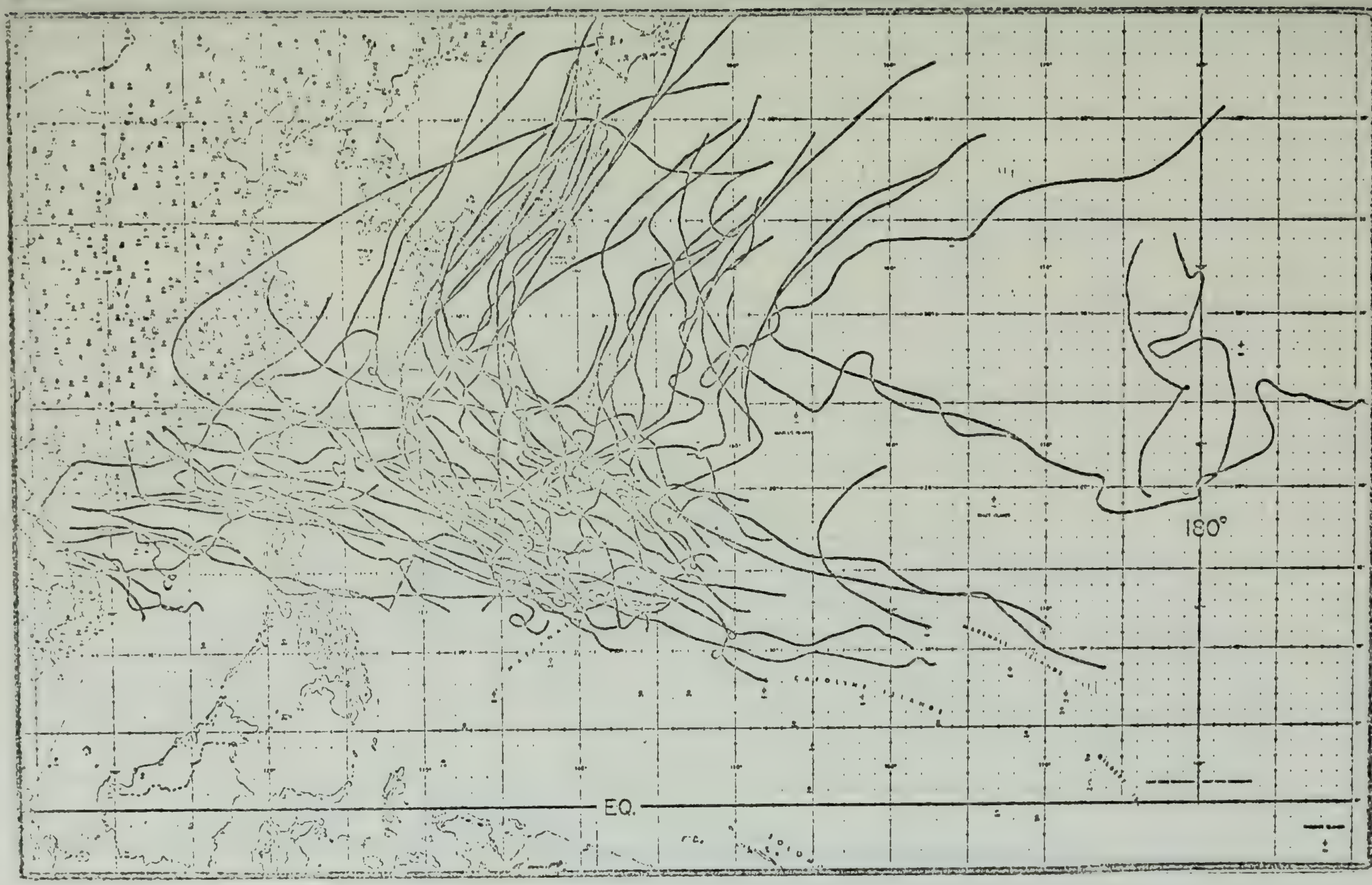

Figure A-6. Tracks of tropical cyclones which at some time were typhoons during the month of September (first half) for the years 1946-1969.

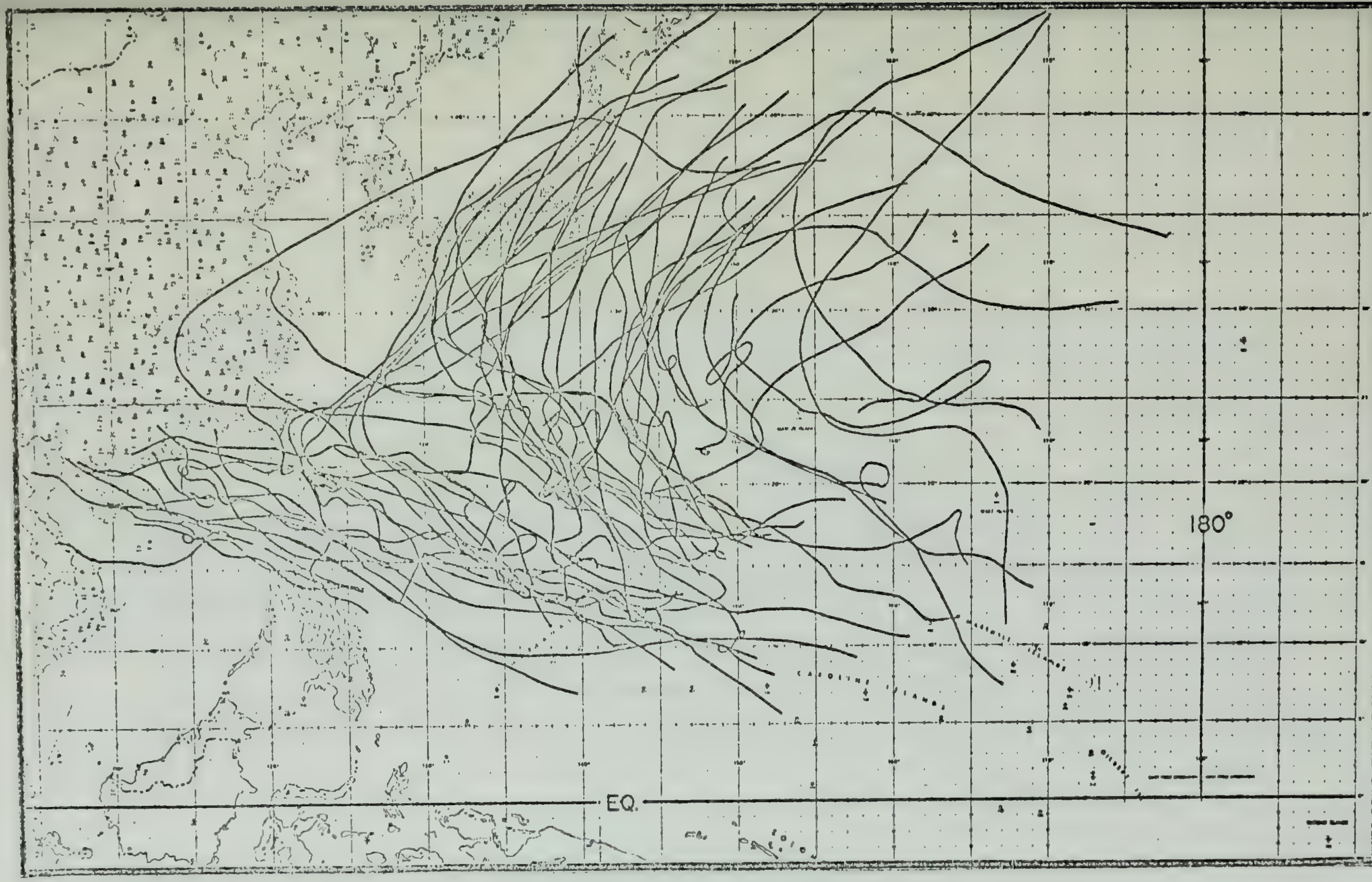

Figure A-7. Tracks of tropical cyclones which at some time were typhoons during the month of September (second half) for the years 1946-1969.

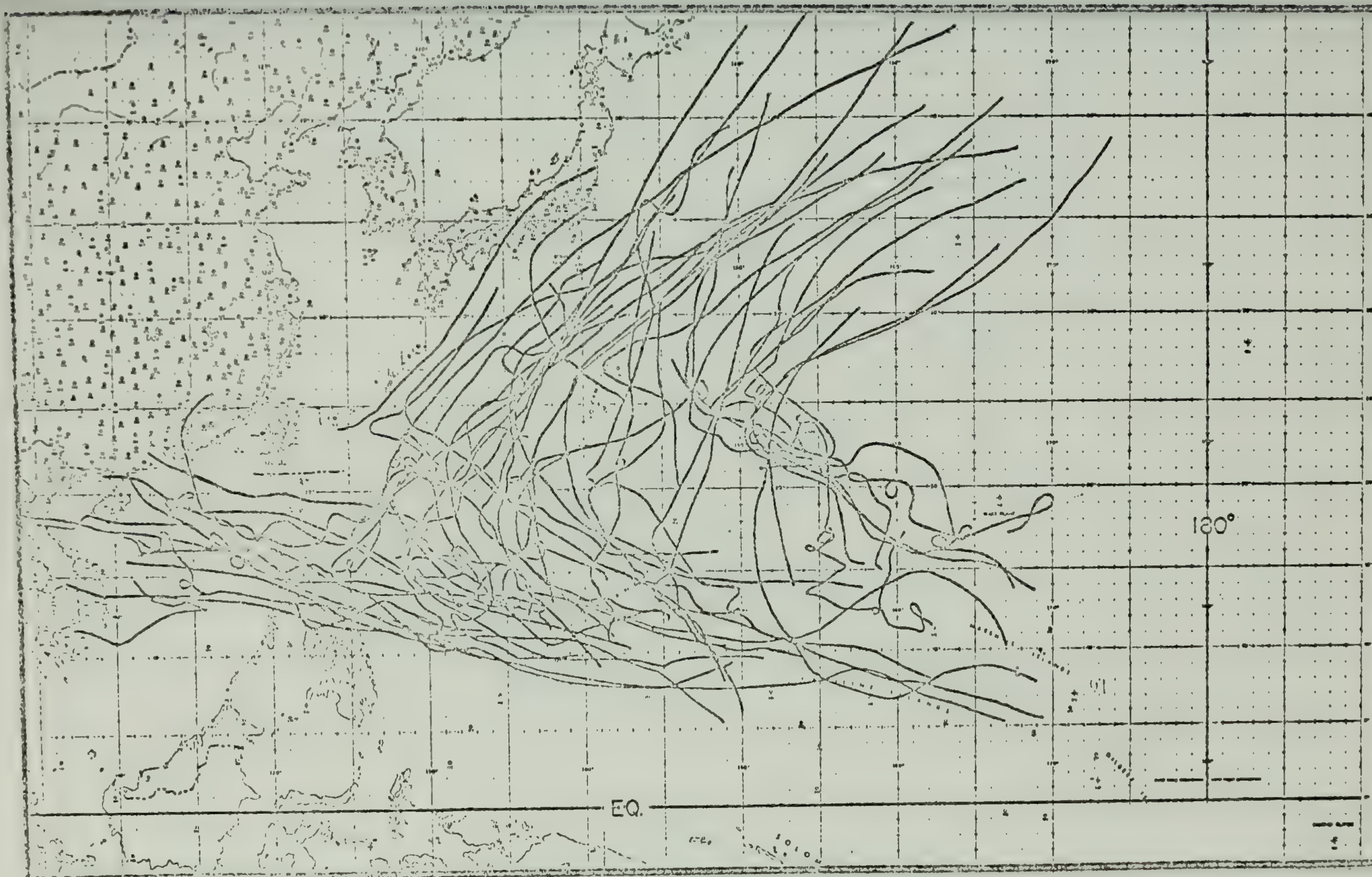

Figure A-8. Tracks of tropical cyclones which at some time were typhoons during the month of October (first half) for the years 1946-1969.

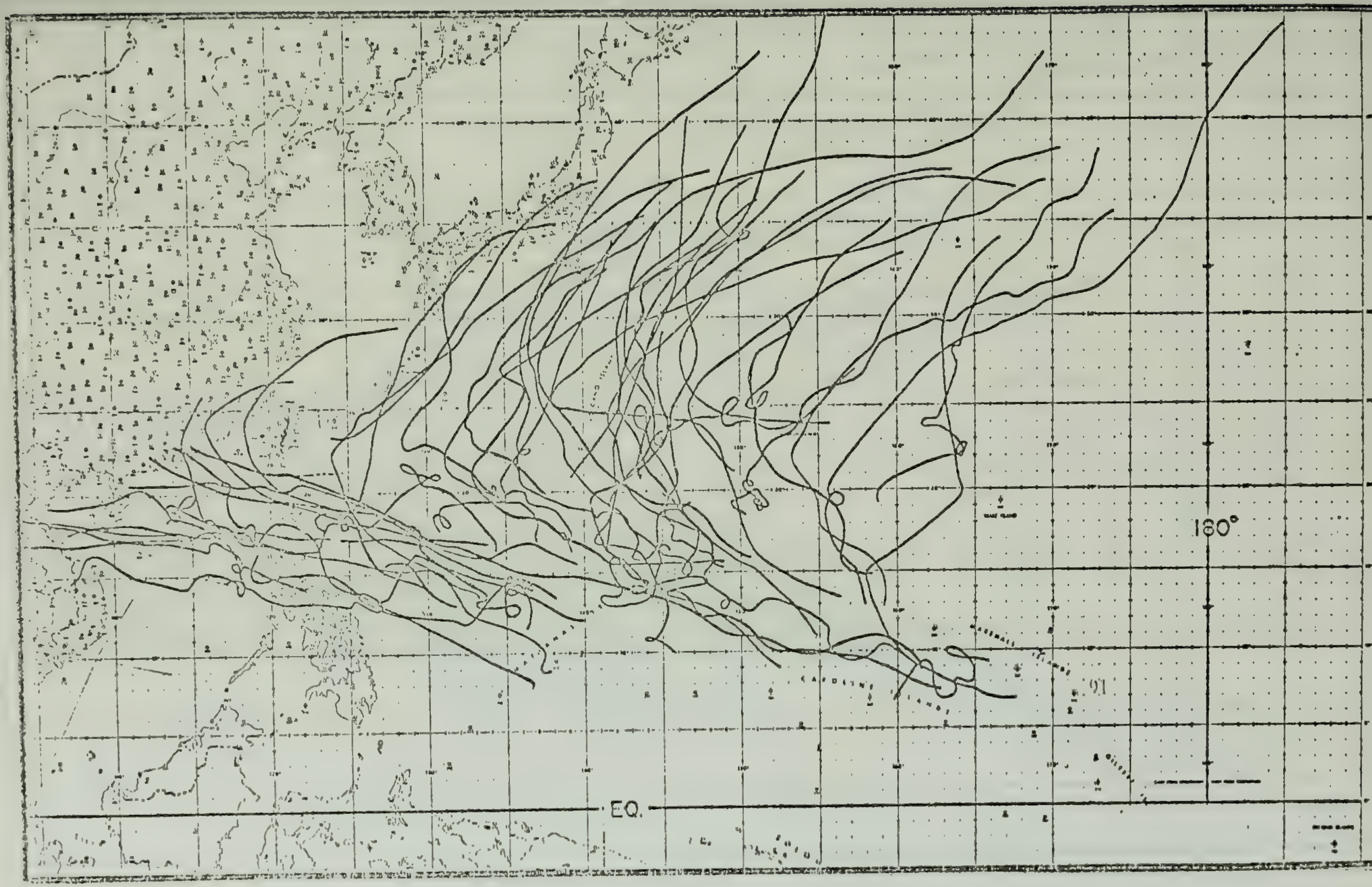

Figure A-9. Tracks of tropical cyclones which at some time were typhoons during the month of October (second half) for the years 1946-1969.

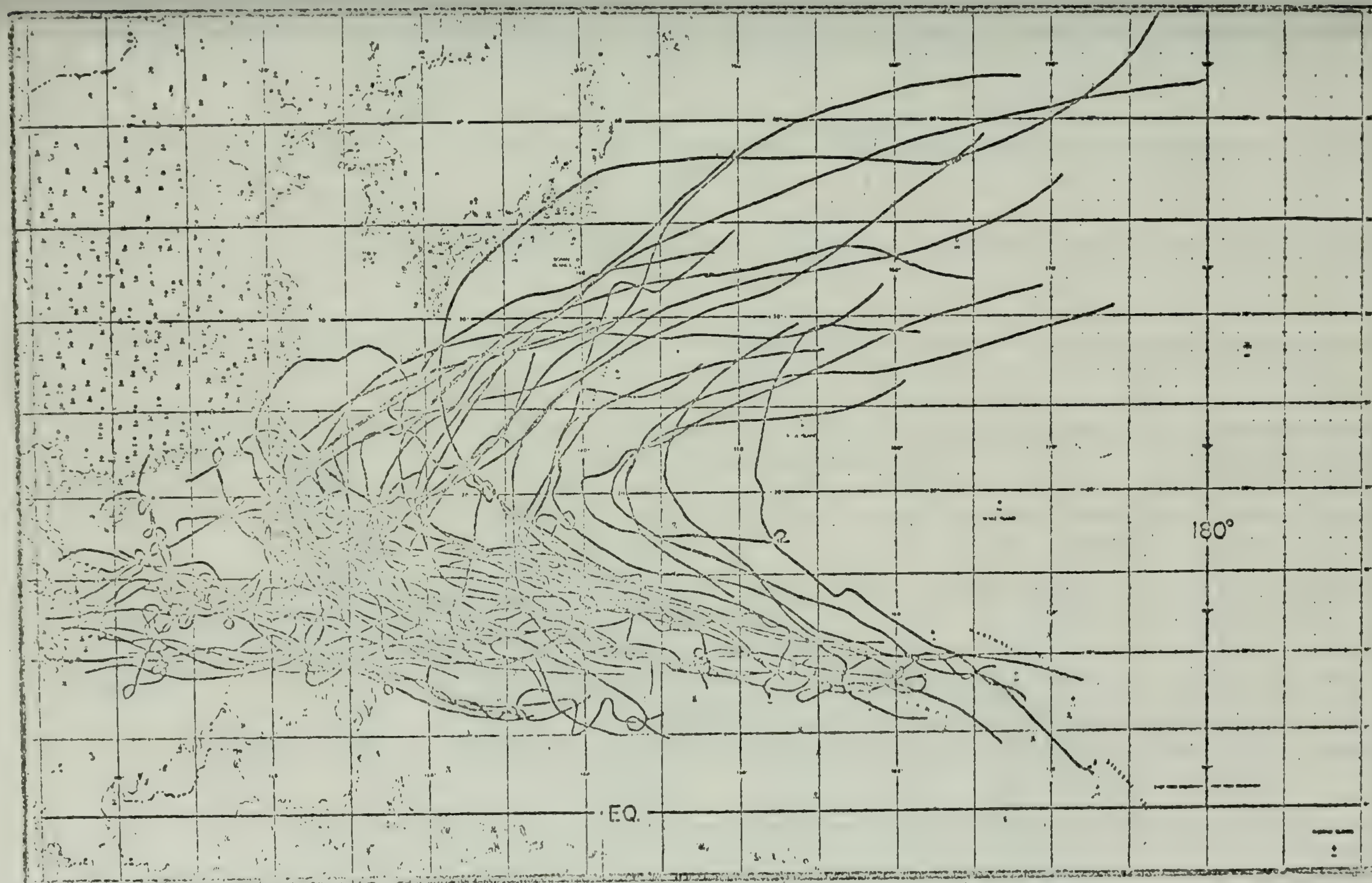

Figure A-10. Tracks of tropical cyclones which at some time were typhoons during the month of November for the years 1946-1969.

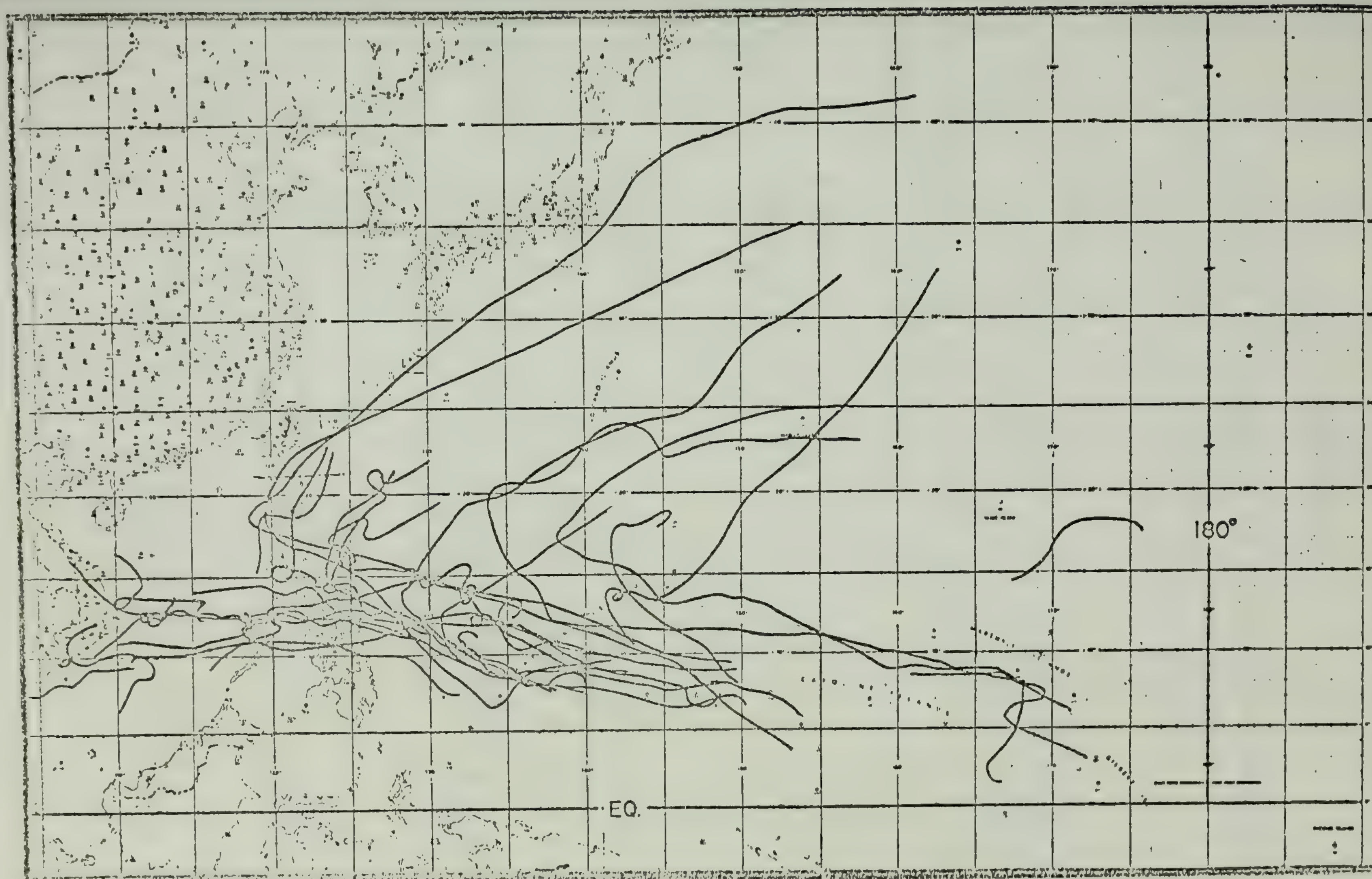

Figure A-11. Tracks of tropical cyclones which at some time were typhoons during the month of December for the years 1946-1969.

APPENDIX B

The following is a summary of pier, anchorage, and buoy facilities available in the South Harbor of Manila. (H.O. Pub. No. 90, 1969.)

1. Anchorages

There are 15 available anchorages in South Harbor of Manila ranging in depths from 17 feet to 32 feet. There are unlimited anchorages outside the breakwater in Manila Bay in depths of 6 to 22 fathoms.

2. Piers

Table G-1 lists the piers available in South Harbor and their characteristics.

3. Facilities

Pier 5 contains a 50-ton crane and 2 cargo sheds.

Pier 9 is the most modern of Manila's port facilities, having covered cargo sheds and water piped to it. Pier 9 contains one 17-ton crane and four 5-ton cranes.

Mobile cranes are available at Luzon Stevedoring and floating and crawler cranes are available at Fernandez Shipyard, Sangley Point.

Two floating cranes of 100-ton capacity each. YD 115 and 171, are also available. A 7.5-ton self-propelled floating crane, YSD 63, is available from Ship Repair Facility for small lifts.

Thirteen mobile cranes of varying capacities and radii are located in the area. Three cruiser type cranes are also available.

Table B-1. Piers available in South Harbor, Manila.

Name	Dimensions	Berth Number	Depth FWD	Depth AFT
Pier 3	1080' X 336'	1	26'	28'
		2	30'	34'
		3	28'	34'
		4	26'	28'
Pier 5	1075' X 333'	1	23'	27'
		2	27'	30'
		4	28'	29'
		5	23'	28'
Pier 9	1095' X 339'	1	24'	28'
		2	27'	30'
		4	28'	30'
		5	24'	28'
Pier 13	1300' X 300'	1	24'	27'
		2	27'	28'
		3	28'	30'
		5	28'	30'
		6	27'	28'
		7	24'	27'
Pier 15	1100' X 340'	1	24'	28'
		2	28'	32'
		4	27'	32'
		5	22'	26'

APPENDIX C

The following is a summary of piers, wharves, anchorages, mooring buoys, and other facilities available in the Port Olongapo complex in Subic Bay (H.O. Pub. No. 918, 1974).

I. Anchorages

There are more than 100 safe anchorages in 12 to 25 fathoms of water with soft mud or coral bottom. Under normal conditions these anchorages are satisfactory, however with strong southwesterly winds in excess of 35 kt ships must steam to their anchors to prevent dragging.

II. Buoys

A total of 18 mooring buoys are presently available in the Port Olongapo complex. Six of these are deep draft mooring buoys. Buoy numbers 3, 19, 21, 23, 24, and 25 can be used for cargo operations and can accommodate vessels of 10,000 tons.

III. Piers and Wharves

Table C-1 lists the piers and wharves available in the Port Olongapo complex and the characteristics of each.

IV. Facilities

Alava wharf contains one 50-ton portal crane which is mounted on rails. The maximum radius for the main hook is 115 feet, it is equipped with a boom extension and it can service all carrier antennas.

Another portal crane is mounted on Rivera Point East. It has a 25-ton capacity with a 90-foot maximum radius for the main hook.

Table C-1. Piers and wharves available in Subic Bay.

Name	Depth Alongside	Dimensions	Height Above MLW	Construction
Alava Wharf	40'	1,600' X 60'	12.5'	Marginal wharf Concrete slab and piles
Leyte Wharf	45'	984' X 80'	12.1	Marginal wharf Concrete slab and piles
Rivera Point South	30'	450' X 60'	10.5'	Marginal wharf Concrete slab and piles
Rivera Point East	30'	900' X 60'	10.5'	Marginal wharf Concrete slab and piles
Rivera Point North	25'	750' X 60'	10.5'	Marginal wharf Concrete slab and piles
Marine Terminal (NSD Pier)	35'	650' X 230'	12.3'	Pier Concrete slab and piles
Ammo Wharf	35'	450' X 80'	9.6	Marginal wharf Sheet steel piles and Bituminous pavement
POL Pier	41'	800' X 40'	-	Pier Concrete slab and piles

APPENDIX D

The following heavy weather plan is a reprint of section 6 of Appendix I to Annex W to COMNAVPHIL OPORD 201-72.

6. Conditions of Readiness

When a typhoon or destructive storm approaches shore installations in the Philippine area, COMUSNAVPHIL will order appropriate conditions of readiness be set. The four (4) conditions of readiness and minimum action required for each are:

a. Condition IV

(1) Definition. Trend indicates a possible threat of destructive winds of force indicated within 72 hours.

(2) Minimum Action. Condition IV is the normal readiness condition in the COMUSNAVPHIL area of responsibility. All commands will continually review plans and bills and make preliminary plans for setting a higher condition or readiness.

b. Condition III

(1) Definition. Destructive winds of force indicated are possible within 48 hours.

(2) Minimum Action

(a) The minimum action will usually not interfere with normal routine and will consist of insuring that plans are completed and that personnel, power plants, and other facilities will be readily available, should conditions II or I be set.

(b) Ships capable of evading the typhoon or storm at sea take on fuel as necessary. Commence preliminary preparations for securing small and yard craft and ships not capable of evasion at sea.

(c) Make preparations for securing small and yard craft and ships not capable of evasion at sea.

(d) Prepare preliminary aircraft evacuation plans based on characteristics and movements of the weather.

c. Condition II

(1) Definition. Destructive winds of force indicated are anticipated within 24 hours.

(2) Minimum Action

(a) All ships capable of evading typhoon or storm at sea or of shifting to a protected anchorage, prepare to get underway on four (4) hours notice.

(b) Ships in unsheltered harbors shall sortie as directed or as soon as practicable if proceeding singly when anticipated winds are considered a hazard.

(c) Ships in protected harbors may be ordered to sortie, may request to sortie, or may remain in port at their discretion if not ordered to sortie. Ships remaining in port shall be prepared to get underway on four (4) hours notice or as directed.

(d) Evacuate and/or secure aircraft at the discretion of the commander directly responsible.

(e) Secure small craft and ships not capable of evasion at sea.

(f) Be prepared to set Condition I on short notice.

d. Condition I

(1) Definition. Destructive winds of force indicated are anticipated within 12 hours.

(2) Minimum Action

(a) In unsheltered harbors, all ships capable of reaching the open sea in time to evade the typhoon, proceed to sea.

(b) Ships in sheltered harbors may put to sea or remain, at their discretion, unless ordered to sortie. Ships remaining in port complete all preparations for riding out the typhoon, shifting berths if required, readying ground tackle, ballasting to reduce wind area and increase stability, running additional mooring lines, and setting steaming watches and anchor details as necessary.

(c) Complete the securing of small craft and ships not capable of evading the typhoon at sea.

(d) Complete all measures for securing shore installations commensurate with the intensity of the forecast winds. Due regard shall be had for the vagaries of violent weather phenomena.

APPENDIX E

Figures E-1 and E-2 represent the estimated resultant speed of advance of a ship in a given sea condition. The original relationships were based on data of speed versus sea state obtained from studies of many ships by James, 1957. They should not be regarded as truly representative of any particular ship (Nagle, 1972).

For example, from Figure E-1, for a ship making 15 kt encountering waves of 16 ft approaching from 030° (relative to the ship's heading) one can expect the speed of advance to be slowed to about 9 kt. Twenty feet seas, under the same conditions, would result in a speed of advance of slightly less than 6 kt. However, it is emphasized that these figures are averages and the true values will vary slightly from ship to ship.

Figure E-3 shows the engine speed required to offset selected wind velocities for various ship types (computed for normal loading conditions).

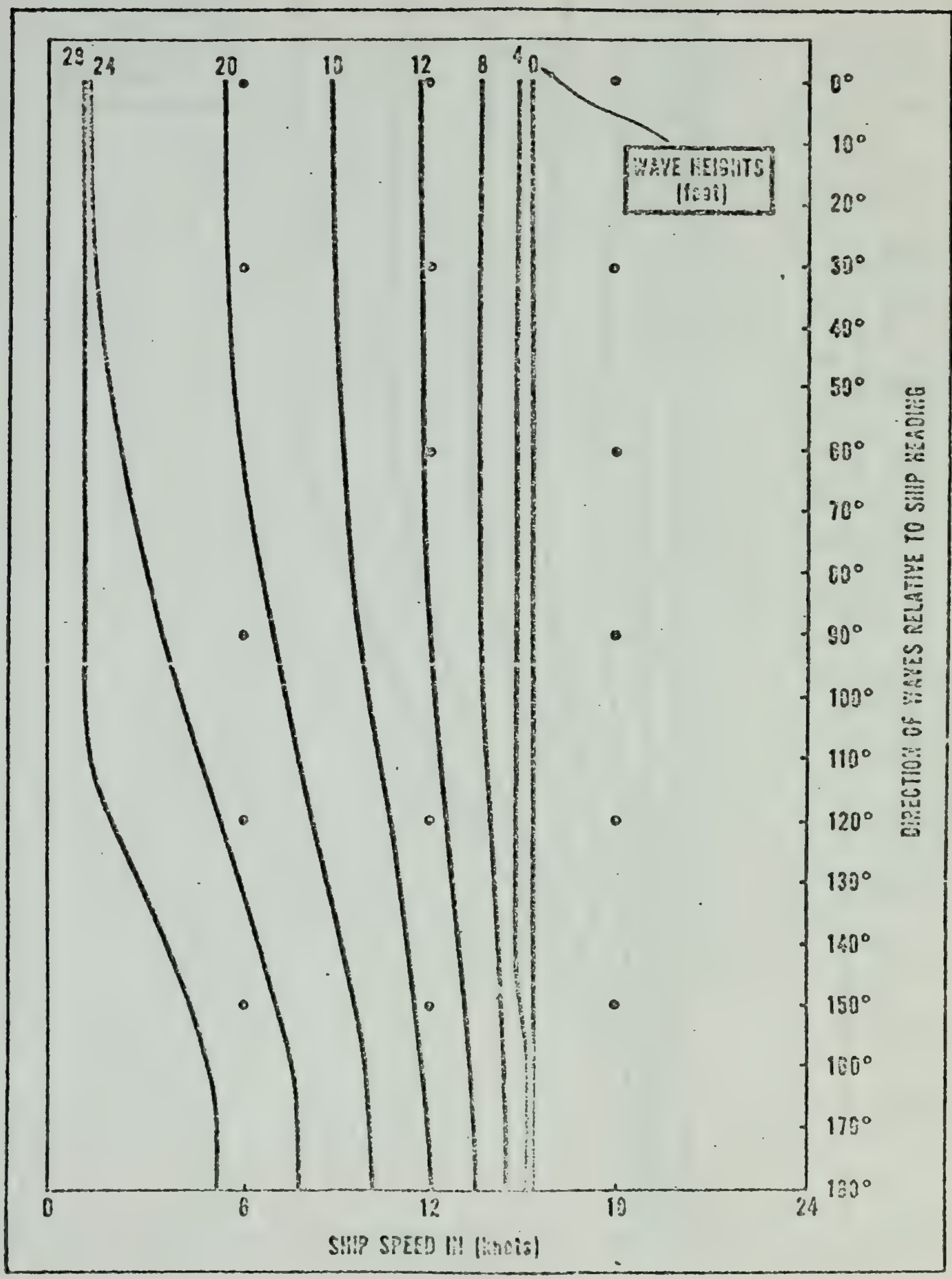

Figure E-1. Ship speed as a function of wave height and wave direction relative to ship's heading (15 kt ship). (From Nagle, 1972.)

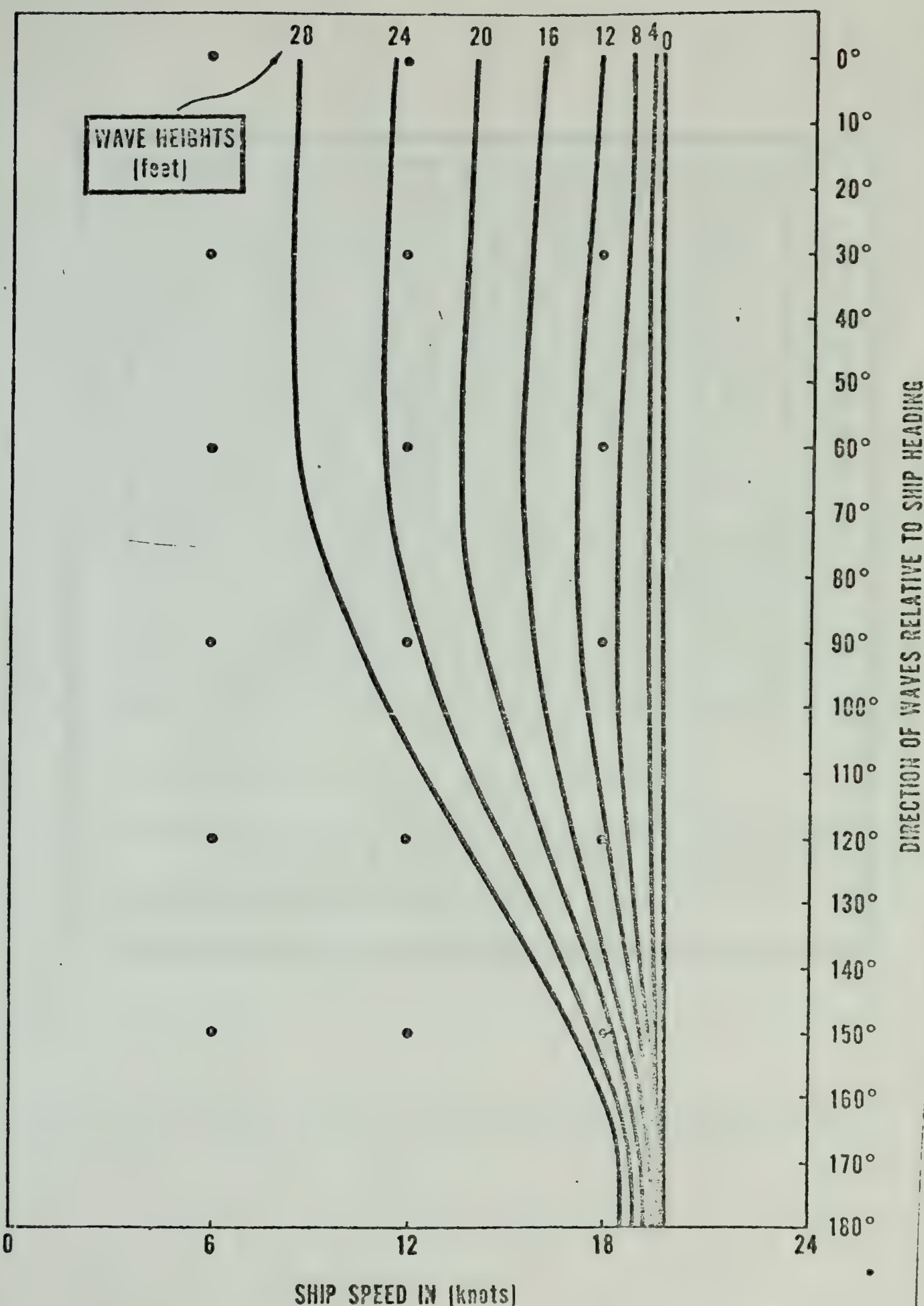

Figure E-2. Ship speed as a function of wave height and wave direction relative to ship's heading (20 kt ship). (From Nagle, 1972.)

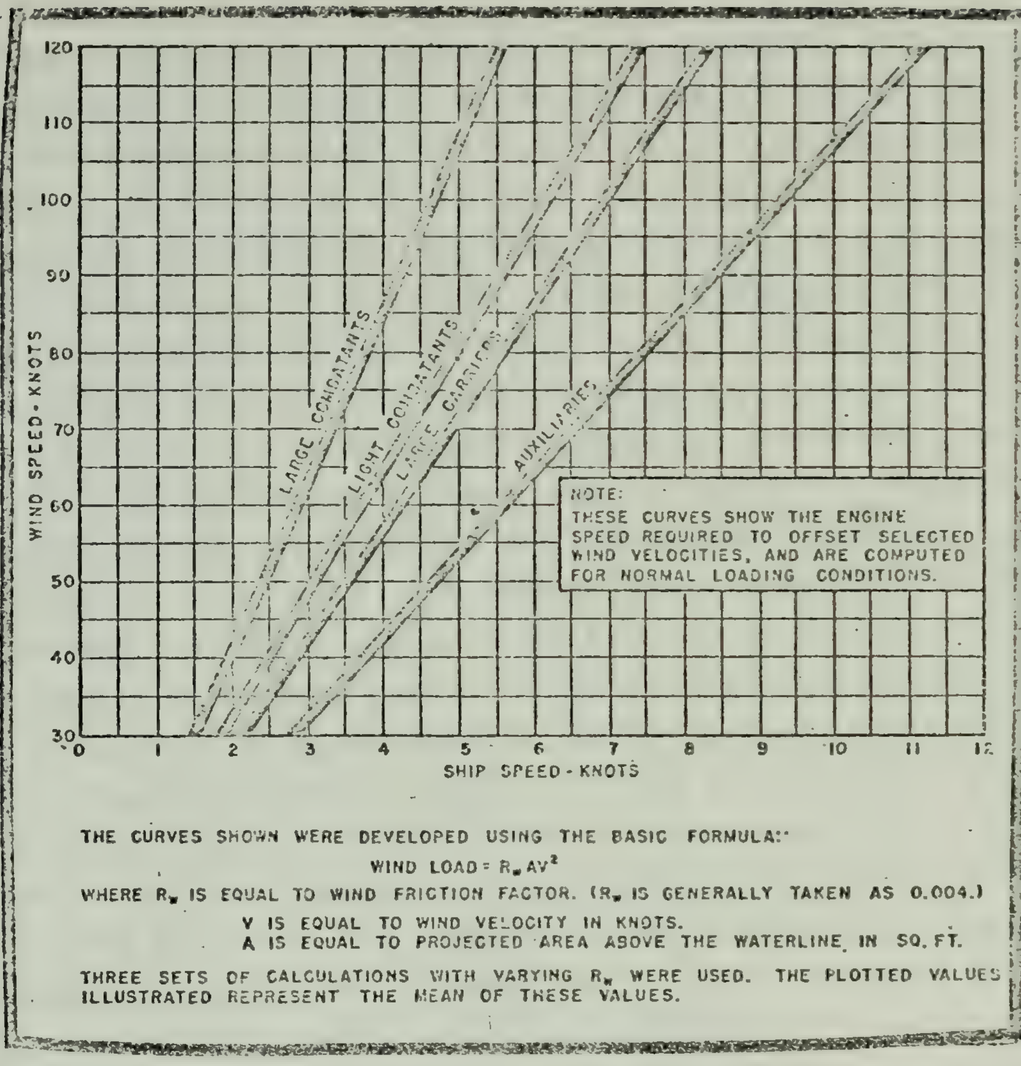

Figure E-3. Engine speed as a function of wind velocity for offsetting force of wind. (From Crenshaw, 1965.)

APPENDIX F

The following are abstracts from commanding officers of ships located in Subic Bay during passage of Typhoon Irma in May, 1966 (COMNAVPHILINST. 3140.2, 1967). Typhoon Irma, originally detected on 11 May 1966 as a tropical depression located near 8N and 137E, rapidly intensified and was designated a typhoon on 12 May 1966. Irma meandered slowly in a west-northwesterly direction until reaching Mindoro Island, approximately 60 n mi due south of Manila, at which time she began a more northwesterly and eventually a northerly course. Figure F-1 shows the best track and intensity of Typhoon Irma as it approached and departed the Philippine Islands. During the period of time that Irma was in close proximity to Subic Bay maximum sustained winds of 80 kt were reported at the storm center. Maximum sustained winds recorded at NAS Cubi Point were 32 kt, experienced at 0623Z on May 18 and 0520Z on May 19. For the greater portion of the period between 0100Z May 18 and 2035Z May 19 the winds recorded were 22 kt or greater. The peak gust reported at NAS Cubi Point was 51 kt at 0700Z on May 19. The winds changed in direction from east-northeast on May 17 to southwest on May 19. Several ships in the harbor during storm passage recorded winds varying in speed between 35-50 kt from the south, which demonstrates the possible variations that can occur in wind speed throughout the Subic Bay area.

As can be seen from the following abstracts the majority of ships in the destroyer class that remained in Subic Bay during the passage of Typhoon Irma would choose to evade at sea if presented with similar circumstances in the future. The smaller vessels, particularly those located at Rivera Point (see Figure F-2), proclaim Subic Bay to be a haven during passage of a typhoon with Irma's intensity and track relative to Subic Bay.

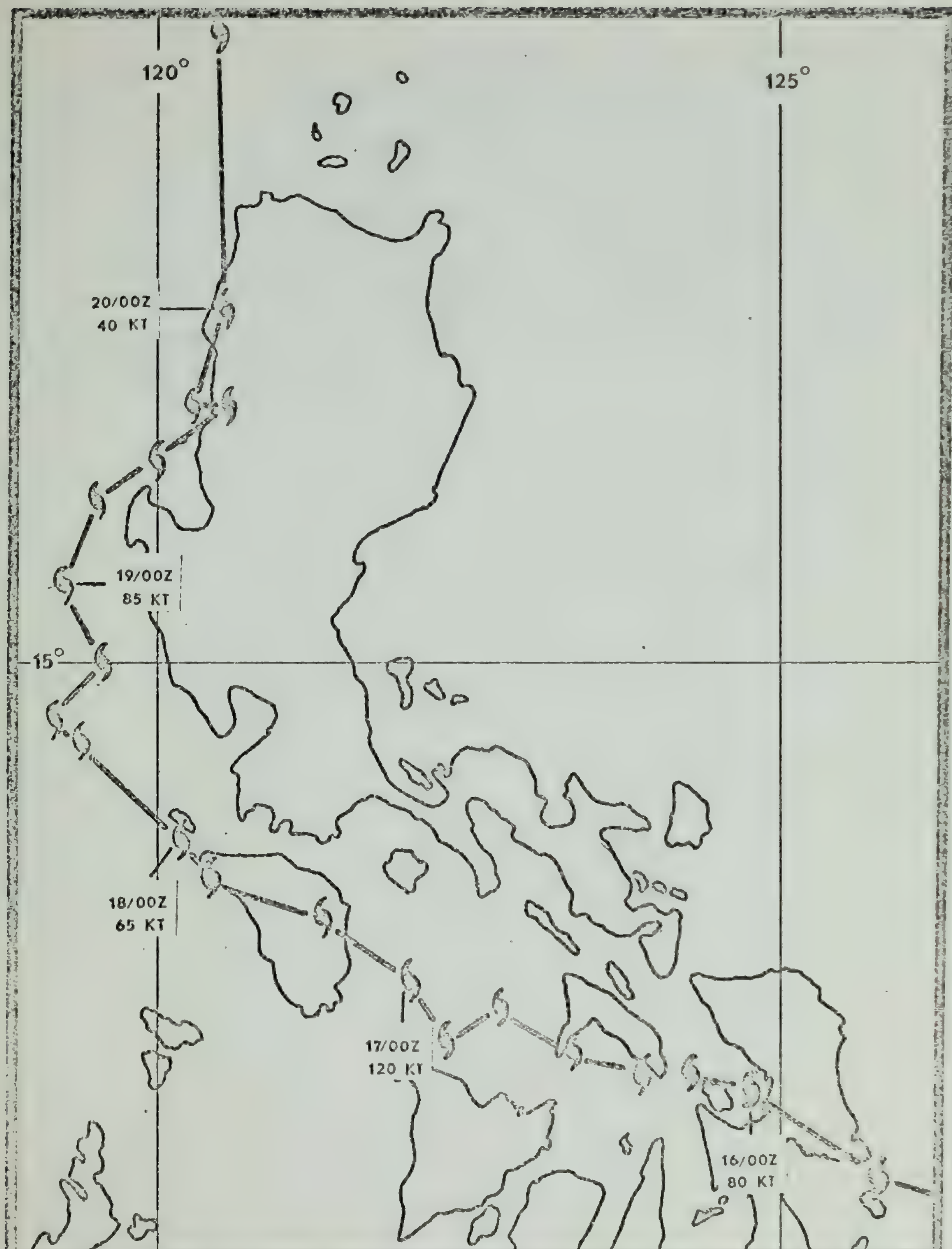

Figure F-1. Positions and intensities of Typhoon "Irma" as it crossed the Philippines between 16 May 1966 and 20 May 1966.

Figure F-2 depicts the anchorages at Subic Bay which were used by the ships electing to remain in the confines of the bay during passage of Typhoon Irma. The ships anchored at Rivera Point, B-1, B-11, and C-8 had little difficulty riding out the storm due to the sheltering effect provided by the mountains to the west and southwest. The anchorages utilized by the remaining ships were subject to dragging and considered to be too exposed to the southerly and southwesterly winds experienced at Subic Bay.

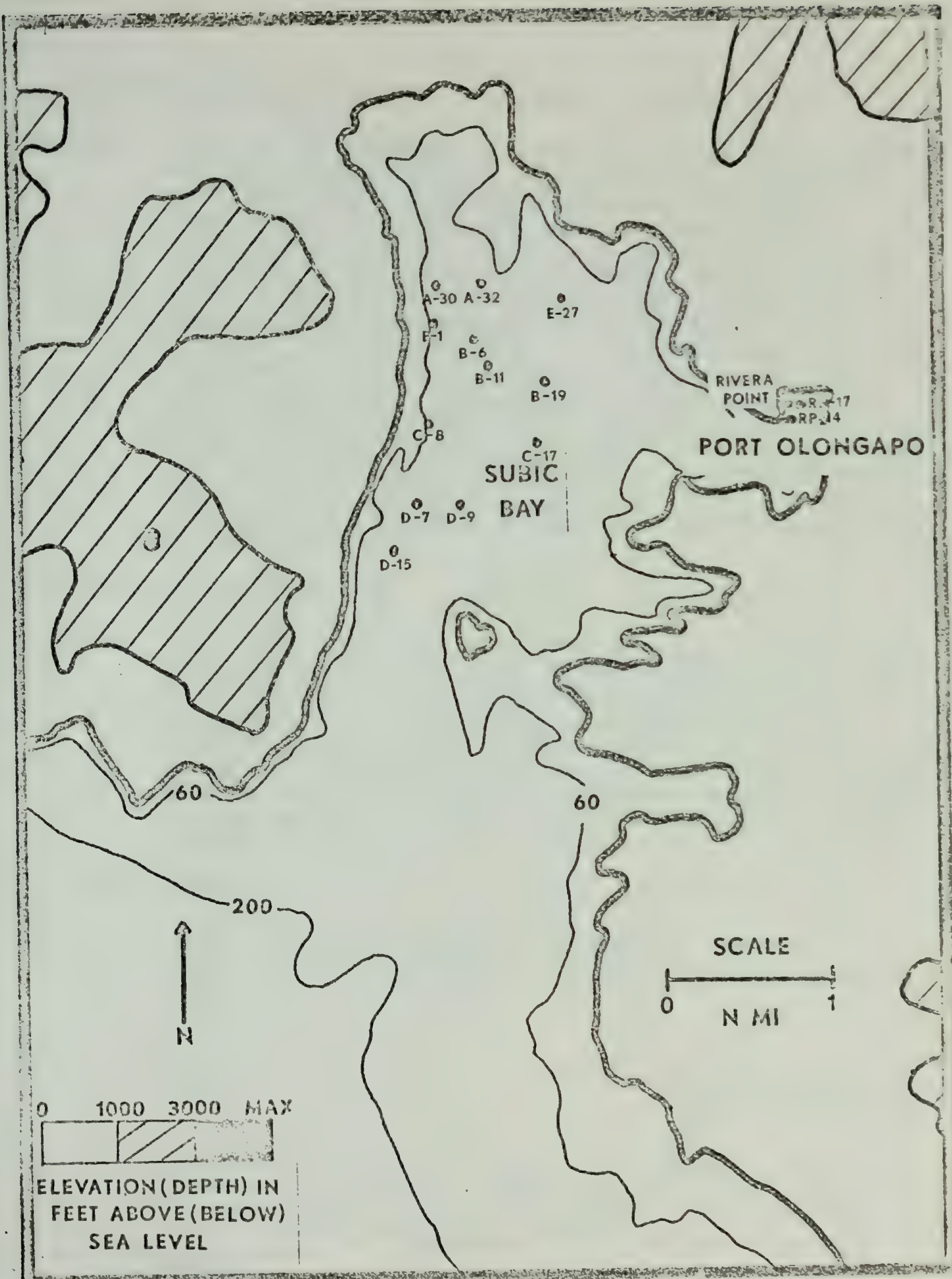

Figure F-2. Map of Subic Bay indicating the anchorage utilized by ships remaining in Subic Bay during typhoon "Irma" in May 1966.

USS WHITE RIVER (LSMR-536)   Location: Anchorage D-7

Remarks: "D-7 is an extremely exposed anchorage necessitating a long scope of chain. The mandatory long scope and continually veering wind precludes even a small ship riding anywhere but near the edge of the assigned anchorage. When ships are assigned adjacent anchorages this can cause the ships to swing dangerously close. It is therefore recommended that adjacent anchorages not be assigned in as exposed locations as D-7. White River was required to remain underway during the night of the 18th with one engine ahead, the other astern two-thirds in order to keep the head into the seas which came from 170 regardless of the wind. This problem was finally solved by dropping another anchor to produce X bridle moor to keep the head at 170 (T), where the ship rode with the minimum discomfort possible under the circumstances."

USS FRED T. BERRY (DD-858)   Location: Anchorage A-32

Remarks: "The ship rode well at anchor until the wind veered into the south. Then the anchor broke ground. The hills seemed to funnel the wind from the south because higher wind speeds were noted at the anchorage than were evident outside the bay. The number of ships at anchor in a rather restricted area allowed very little room to maneuver when an anchor failed to hold. Do not consider Subic Bay an ideal typhoon haven."

USS HENRY COUNTY (LST-824)   Location: Rivera Pier, Berth 17

Remarks: "This location excellent for typhoon mooring, negligible sea and swell. Winds moderated by trees and structures ashore."

USS ST. CLAIR COUNTY (LST-1096)   Location: Rivera Pier, outboard USS HENRY COUNTY

Remarks: "Inner basin well sheltered at all times. Heavy winds cause surging. Seas appeared relatively calm in basin and only possible danger observed from heavy rain. This berth appears to be an ideal typhoon haven."

USS BRONSTEIN (DE-1037)   Location: Anchorage B-19

Remarks: "(1) It appeared that when the winds shifted around from North to South that a marked funnel effect of the wind was created in the Bay. Ships that sortied because of dragging anchors, and who remained at sea within 20 miles of the harbor entrance consistently reported wind velocities that were 10-15 knots below that experienced inside the bay. This effect was particularly noted during the afternoon and early evening of 19 May.

(2) During the early morning hours of 19 May when the winds were shifting from North to South, the ship rolled severely, up to 30° for about four hours.

(3) Wind velocities in the vicinity of anchorage B-19 (exposed to open sea) were generally 10-15 knots higher than those reported by a ship at buoy 25, that position being relatively secure from the open sea.

(4) Fresh water proved to be a problem for most ships in the Bay. Since the Fleet Guide for Subic Bay indicates the harbor water to be contaminated, potable water could not be distilled. All ships should, if possible, top off with fresh water before moving to typhoon anchorage.

(5) Navigation was no problem throughout the passage of the typhoon. Visual and/or radar points for fixing the ship's position are excellent.

(6) The Subic Bay harbor chart, HO 2093, in the area of the anchorages is very poorly marked with respect to bottom composition. A survey of the anchorage areas should be conducted and the chart so annotated.

(7) BRONSTEIN, in anchorage B-19, used a stem mounted patent stockless anchor with 120 fathoms of chain at the water's edge. The ship as far as can be determined, did not drag anchor at all during the period of the typhoon's passage. Success of this anchorage may be attributed to the following factors:

(a) A full 6 to 1 scope of chain was used (water depth at B-19 is 21 fathoms).

(b) The stem mounted focal point of the chain vice the standard location on either side of the bow resulted in the ship not swinging back and forth in an arc across the direction of the wind as much as normally would be expected and thus not working the anchor loose.

(c) The deeper water anchorages nearest the main ship channel appeared to have much better holding ground than those in other locations. Several ships between BRONSTEIN and the northern side of the bay dragged their anchors.

(d) In summary, BRONSTEIN rode out the typhoon in a satisfactory manner. Subic Bay is considered to be a safe typhoon haven under the following conditions:

1. Sustained wind velocities do not exceed 60 knots.

2. Anchorage assigned to ships favor those nearest the main ship channel or the mooring buoys in vicinity of ALAVA piers.

3. Anchorages assigned are spaced so as to give at least 1,000 yards between ships (Normal anchorage radius is 600 yards.)"

USS RECLAIMER (ARS-42) Location: Anchorage A-30

Remarks: "Regarding Subic Bay as typhoon haven: Excellent."

USS BRIDGET (DE-1024) Location: Anchorage B-3
Anchorage B-9
Anchorage B-10
Anchorage C-3

Remarks: "The full effect of Typhoon Irma was never felt in Subic Bay, maximum winds experienced being only 50 knots and seas remaining moderate throughout. Nevertheless, BRIDGET found assigned anchorages unsatisfactory even under these conditions for the following reasons:

a. BRIDGET experienced severe dragging in two of the assigned berths, B-3 and B-10, despite attempts to maintain position by the use of rudder and engine.

b. In all assigned anchorages proximity to unmarked shoal water was less than 1,500 yards.

c. Lighted visual aids to navigation, vital to continuous accurate fixing, are totally lacking in the western portion of Subic Bay and few are available near the Naval Base. Accurate determination of dragging under these conditions is impossible. Recommendations:

1. That Subic Bay not be utilized as a typhoon haven due to lack of reliable, safe anchorages with good holding ground.

2. That, even with gale conditions or less, the Bravo anchorages not be utilized due to the apparent lack of good holding ground, the proximity of unmarked shoal water, and the lack of adequate navigational aids particularly around Mayanga Islands.

3. That additional lighted, navigational aids be established, particularly on the Western Coast of the mainland to facilitate accurate fixing under any conditions."

USS TILLAMOOK (ATA-192 Location: Rivera Pier, Berth 14

Remarks: "Safe for small ships."

USS WHETSTONE (LSD-27) Location: Anchorage C-8

Remarks: "a. Used 120 fathoms chain starboard anchor, 25 fathoms to port anchor, did not drag anchor.

b. Used engines, RPM for 2.5 knots during height of storm.

c. Subic Bay considered satisfactory typhoon haven for this type ship.

d. Preference in future like situations would be to to sea and evade."

USS MASSEY (DD-778) Location: Anchorage B-11 until 0800 19 May then at sea.

Remarks: "Subic Bay is a good typhoon haven, even with southerly winds, if a scope of chain of 6 or 7 to 1 can be maintained. Ninety fathoms of chain was used in 20 fathoms of water. If one hundred twenty fathoms of chain had been available, dragging would have been less likely to occur."

USS ENGLAND (DLG-22) Location: Buoy 25

Remarks: "Remarks regarding Subic Bay as Typhoon Haven: ENGLAND had no difficulty at Buoy #25. On the afternoon and evening of the 19th with the wind from about 185°-205° at 30-40 knots, ships head into the wind, very little strain was being taken on the mooring chain, this indicated a possible current in the bay in a direction opposite to the wind. Earlier with the wind from 050°., ship head into the wind ENGLAND used 1 knot of engine speed for each 10 knots of wind over 30 knots. At no time during this period was a heavy strain taken on the mooring chain. There was very little rolling and no pitching observed. The berth was an excellent one which could have taken at least twice the amount of wind experienced without appreciable danger if ship engines were used to each chain strain."

USS RICHARD E. KRAUS (DD-849) Location: Anchorage B-1

Remarks: "B-2 - 13 apparently difficult anchorage to maintain. We were only ship to ship to remain in anchorage. B-1 held firmly and appeared to be protected from Southwest and Westerly winds by Petambu Point. Had 120 fathoms of chain to 5,000 lb. Bowers Stockless anchor."

USS KLONDIKE (AR-22) Location: Anchorage E-27
Anchorage D-15
Anchorage D-9

Remarks: "KLONDIKE dragged anchor in all three anchorages. Close proximity of anchorages E-27 and D-15 to land and shoal water precluded veering chain to a sufficient scope to afford proper holding. Anchorage D-9 was far more desirable, in that its location permitted maximum utilization of KLONDIKE's chain (i.e., 135 fathoms). Although KLONDIKE experienced anchor drag (approximately 400 yards), with this amount of chaine there was sufficient "sea room" to allow the anchor to "bite in" and also give assistance with the main engines. Recommendation: In view of the comparative moderate typhoon winds and the amount of anchor drag experienced during the typhoon, it is recommended that ships not be assigned anchorages in Subic Bay if winds in excess of 55 knots are anticipated. Additionally, large ships with limited maneuvering capability should be assigned anchorages with plenty of sea room and consideration should be given to limited anchorage assignments to fewer ships."

USS MORTON (DD-948) Location: Anchorage B-6
Anchorage C-17

Remarks: "(1) MORTON initially assigned anchorage B-6, but dragged anchor at 181300H; shifted anchorage to vicinity C-17.

(2) Depth of water in Subic Bay is too great for Destroyer types, e.g., all anchorages 20 fathoms, maximum chain available 135 fathoms, therefore negating the use of 7-1 scope ratio.

(3) Subic Bay would be considered safe haven if buoys were installed present anchorages.

(4) Under present conditions Subic Bay, had Typhoon IRMA been of greater energy, ships should stand to sea and maneuver to avoid."

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